PUBLIC ROADS

A JOURNAL OF HIGHWAY RESEARCH

FEDERAL WORKS AGENCY
PUBLIC ROADS ADMINISTRATION

VOL. 21, NO. 4 ▽ JUNE 1940

PERFORMING BENDING TESTS ON BITUMINOUS MIXTURES

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PUBLIC ROADS ▸▸▸ *A Journal of Highway Research*

Issued by the

FEDERAL WORKS AGENCY

PUBLIC ROADS ADMINISTRATION

D. M. BEACH, *Editor*

Volume 21, No. 4 June 1940

The reports of research published in this magazine are necessarily qualified by the conditions of the tests from which the data are obtained. Whenever it is deemed possible to do so, generalizations are drawn from the results of the tests; and, unless this is done, the conclusions formulated must be considered as specifically pertinent only to described conditions.

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CHEMICAL TREATMENT OF CHERT-GRAVELS FOR USE IN BASE-COURSE CONSTRUCTION

BY THE DIVISION OF TESTS, PUBLIC ROADS ADMINISTRATION

Reported by E. A. WILLIS, Associate Highway Engineer, and P. C. SMITH, Junior Highway Engineer.

THIS REPORT is the fourth in a series describing investigations of materials for base-course construction. Previous reports have described laboratory and circular track tests on sand-clay and sand-clay-gravel materials and on nonplastic materials with admixtures of water-retentive chemicals.

The present report is the result of investigations in which three chert-gravels from Alabama were tested in the outdoor circular track. The chert-gravels tested were representative of a class of local materials found to such an extent in the Southeastern United States as to be important in road construction. They consist of mixtures of coarse chert particles and fine material made up of dust of fracture and clay. As a class they have given satisfactory service when used as surface courses, but have caused failures in numerous instances when used as base courses because of excessive amounts of the active binder which they usually contain.

Sand and granulated slag were used to reduce the plasticity index of the plastic chert-gravel that was investigated. Due to the presence of finely divided silica in the chert it was felt that the addition of lime might reduce the activity of the natural binder and form a cementing agent through puzzolanic action. Consequently, an admixture of hydrated lime was used in three sections to determine its effect on the behavior of the chert-gravels as base courses.

The circular track used in these investigations was the same as was used in the studies of water-retentive chemicals as admixtures with nonplastic road-building materials which have been reported previously.[1] The tire equipment was size 30 by 5, of the high-pressure type, requiring an inflation pressure of 80 pounds per square inch. The load imposed by each wheel was 800 pounds until near the end of the test when it was increased to 1,000 pounds.

Distributed traffic, which was used for compacting the base course and the surface treatment, was obtained by gradually shifting the rotating beam longitudinally with respect to its axis of rotation. Concentrated traffic, which was used after the surface treatment had been constructed, was obtained by locking the sliding pivot of the beam in such a position that the wheels pursued two concentric circular courses whose center lines were about 2½ inches on either side of the center line of the test sections.

COMPOSITION AND TESTING OF TRACK SECTIONS DISCUSSED

Six sections were tested in this investigation. Each section was 18 inches wide, 6 inches deep, and approximately 6.3 feet long.

Three chert-gravel materials were used in the track sections. Chert A was a mixture of materials from two pits in Alabama having similar test constants. This mixture had a liquid limit of 46 and a plasticity index of 20. Chert B was from a single pit in Alabama and had a liquid limit of 25 and a plasticity index of 2. Chert C was a composite of 11 samples which had been taken from chert base courses in Alabama at locations where base failures had occurred.

The compositions of the six sections in the track are given in table 1. Section 1 consisted of 45 percent of chert A and 55 percent of Potomac River sand; section 2 consisted of 43 percent of chert A, 52 percent of Potomac River sand, and 5 percent by weight of hydrated lime; section 3 consisted of 35 percent of chert A and 65 percent of granulated slag; section 4 consisted entirely of chert B; section 5 consisted of 95 percent of chert B and 5 percent of hydrated lime; and section 6 consisted of 95 percent of chert C with a 5 percent hydrated lime admixture. The quantity of sand and granulated slag used in sections 1 and 3 was that required to reduce the plasticity index of chert A from 20 to approximately 6. Section 2 was identical with section 1 except for the admixture of 5 percent of hydrated lime.

The gradings and soil constants of the mixtures used are given in table 2. The effect of the hydrated lime in increasing the liquid limit and reducing the plasticity index can be seen by comparing the analyses of section 1 with section 2 and section 4 with section 5.

TABLE 1.—*Composition* [1] *of sections of test track*

Section No.	1	2	3	4	5	6
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Chert A	45	43	35			
Chert B				100	95	
Chert C						95
Potomac River sand	55	52				
Granulated slag			65			
Hydrated lime		5			5	5

[1] Percentage based on dry weight.

TABLE 2.—*Gradings and soil constants of mixtures used in track*

Section No.	1	2	3	4	5	6
Grading:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Passing 1-inch sieve	100	100	100	100	99	100
Passing ¾-inch sieve	99	99	100	97	92	93
Passing ⅜-inch sieve	89	90	92	85	79	75
Passing No. 4 sieve	80	81	87	70	63	60
Passing No. 10 sieve	65	64	60	55	46	44
Passing No. 40 sieve	44	37	35	44	33	29
Passing No. 200 sieve	19	12	19	36	26	15
Passing 0.005 mm	7	5	6	11	11	9
Dust ratio [1]	43	32	54	82	79	52
Tests on material passing No. 40 sieve:						
Liquid limit	22	28	24	25	36	34
Plasticity index	8	0	5	2	0	0

[1] $\text{Dust ratio} = 100\left[\frac{\text{percentage passing No. 200 sieve}}{\text{percentage passing No. 40 sieve}}\right]$.

[1] Studies of Water-Retentive Chemicals as Admixtures with Nonplastic Road-Building Materials, by E. A. Willis and C. A. Carpenter. PUBLIC ROADS, vol. 20, No. 9, November 1939.

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In constructing the test sections sufficient water was added to the aggregates to bring the fraction passing the No. 4 sieve to its optimum moisture content as previously determined by the A. A. S. H. O. standard compaction test, with a slight excess for wetting the coarse aggregates.

The moisture contents of all sections immediately after being placed in the track and at the time of failure or end of test are shown in table 3, together with the optimum moisture contents for the fraction of the materials passing the No. 4 sieve.

TABLE 3.—*Moisture contents immediately after construction and at the end of test, and optimum moisture contents of the fraction passing the No. 4 sieve*

Section No.	Optimum moisture content of fraction passing No. 4 sieve [1]	Moisture content of sections after placing [2]	Moisture content of sections at time of failure or end of test [2]
	Percent	*Percent*	*Percent*
1	11.6	10.4	9.9
2	14.0	11.2	14.6
3	14.6	10.0	12.3
4	16.1	15.2	15.1
5	19.6	16.0	19.0
6	15.8	10.0	16.7

[1] Based on the dry weight of the portion of the aggregate passing the No. 4 sieve.
[2] Based on the dry weight of the total material.

The procedure for preparing the materials for the track tests, constructing the test sections, and surface-treating them, was as follows:

1. The aggregates were proportioned by weight from the stock materials and were thoroughly mixed before any water was added.
2. Hydrated lime was added to the materials for sections 2, 5, and 6 and thoroughly incorporated in the dry mixing process.
3. Water was added and mixing continued to distribute the moisture.
4. The moistened mixtures were then placed in the trough of the track in two approximately equal layers, each layer being compacted with pneumatic-tired traffic uniformly distributed over the surface.
5. Compaction with distributed traffic was continued on the top layer for 20,000 wheel-trips, at which time no further subsidence was noted and all sections were in suitable condition for testing.
6. The sections were trimmed smooth.
7. A prime coat consisting of 0.3 gallon per square yard of light tar was applied and allowed to cure.
8. A surface treatment consisting of 0.4 gallon of hot tar and a cover of 50 pounds per square yard of ¾-inch-maximum-size stone was constructed.
9. The treated surface was consolidated by an additional 20,000 wheel-trips distributed over the surface. The surface was well sealed by then and showed no movement.

RATING OF SECTIONS BASED ON APPEARANCE AND AMOUNT OF DISPLACEMENT

The behavior of the materials under test was judged on the basis of the appearance of the sections at various stages of the tests supplemented by measurements of vertical displacements of the surface. Previous reports have described the transverse [2] and longitudinal [3] profilometers with which the measurements were made.

[2] Circular Track Tests on Low-Cost Bituminous Mixtures, by C. A. Carpenter and J. F. Goode, PUBLIC ROADS, June 1936.
[3] A Study of Sand-Clay-Gravel Materials for Base Course Construction, by C. A. Carpenter and E. A. Willis, PUBLIC ROADS, March 1939.

By means of a planimeter, the area between the initial and each succeeding transverse profile made at that station was measured. That area divided by the width of the track (18 inches) gave the vertical displacement, and the average for the two stations on the section gave the average vertical displacement for that section.

The area between the initial and each succeeding longitudinal profile made in that wheel lane was measured for each section and the area of vertical displacement determined. That area divided by the length of the wheel lane gave the depth of rutting and the average for the two wheel lanes gave the average depth of rutting for the section.

An average vertical displacement of about 0.25 inch, measured after the sections had been surface treated and subjected to the action of concentrated traffic, was observed to be sufficient to cause noticeable damage to the bituminous surface. This is in agreement with conclusions reached in previous investigations using the same apparatus. The amount of rutting measured by the longitudinal profilometer averaged approximately 0.5 inch at the same time the average vertical displacement was 0.25 inch. Since the average vertical displacement depends upon the width of the track, a comparison of average vertical displacement with depth of rutting is only valid for a track having a width of 18 inches.

Changes in behavior of the various sections under altered test conditions are clearly shown by abrupt changes in the slopes of the displacement curves, figure 1.

The schedule of traffic applications and changes in water elevation, with notations on the behavior of the five test sections, are given in table 4. Initial profile measurements were taken at 40,000 wheel-trips when concentrated traffic was started. The average vertical displacements as measured by the transverse profilometer and the average depth of ruts as measured by the longitudinal profilometer subsequent to that time are shown in figure 1.

All sections compacted well and showed little movement under distributed traffic with no water in the sub-base (0 to 40,000 wheel-trips).

Water was admitted and the level raised to one-half inch above the top of the subbase at 40,000 wheel-trips. The sections were allowed to absorb water overnight. Movement was noticed in the base course of section 4 (chert B) as soon as testing with concentrated traffic was started. At 40,572 wheel-trips, or only 572 wheel-trips after water was admitted to the sub-base, this section had failed completely and was so rough that it had to be removed and replaced with a dummy section before testing could be continued.

Profiles of section 4 after it had failed showed an average vertical displacement of 0.78 inch and an average depth of rut of 0.93 inch. The condition of the section at 40,572 wheel-trips is shown in figure 2.

Testing with concentrated traffic was resumed at 44,972 wheel-trips, 4,400 wheel-trips of distributed traffic having been applied to compact the surface treatment on the dummy section which replaced section 4.

Movement was noticed in section 1, the sand-chert A mixture, soon after testing was resumed. This continued throughout the testing period from 44,972 wheel-trips to 84,400 wheel-trips with the water level one-half inch above the top of the sub-base. The rutted condition of section 1, caused by lack of stability in the base course, is shown in figure 3.

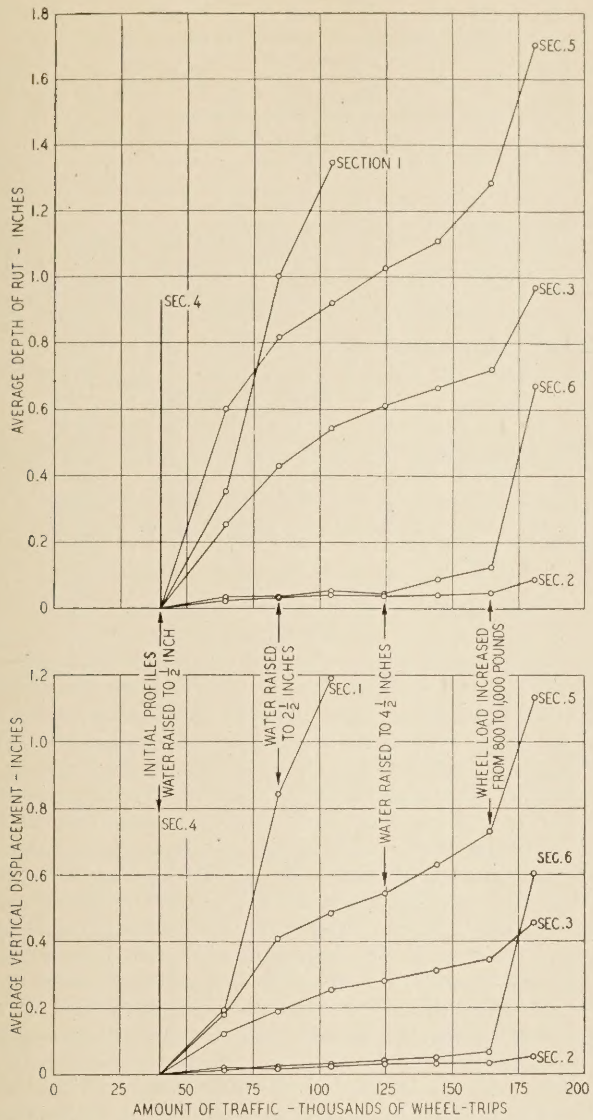

FIGURE 1.—RATE OF SURFACE DISPLACEMENT OF TRACK SECTIONS UNDER TRAFFIC.

Section 5, constructed of chert B with a 5-percent admixture of hydrated lime, was slightly unstable when tested with the water at the ½-inch level. Wheel tracks were plainly visible on the surface and average vertical displacement exceeded 0.4 inch.

Sections 2, 3, and 6 remained in good condition during this period of testing, although the rate of average vertical displacement for section 3, the chert A-slag section, indicated that continued traffic with water at the ½-inch level would ultimately have produced failure.

FIGURE 2.—APPEARANCE OF SECTION 4 AT 40,572 WHEEL-TRIPS, OR 572 WHEEL-TRIPS AFTER START OF TESTING WITH CONCENTRATED TRAFFIC.

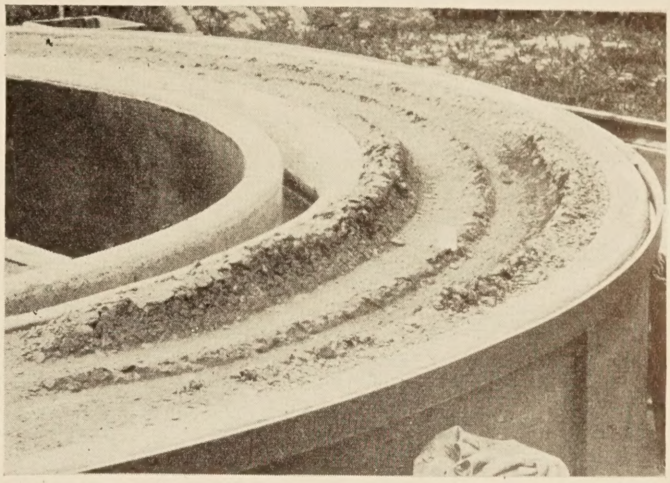

FIGURE 3.—APPEARANCE OF SECTION 1 AT 84,400 WHEEL-TRIPS, AFTER TESTING WITH WATER ½ INCH ABOVE THE TOP OF THE SUB-BASE.

ONLY ONE SECTION REMAINED IN GOOD CONDITION THROUGHOUT ENTIRE TEST

Water was raised to 2½ inches above the top of the sub-base at 84,400 wheel-trips and testing with concentrated traffic was continued. Under these test conditions section 1 failed completely; sections 3 and 5 were slightly unstable with increasing amounts of vertical displacement; and sections 2 and 6 remained in good condition. Section 1 was removed at 124,400 wheel-trips and replaced with a dummy section.

Testing was then continued with the water raised to 4½ inches above the top of the sub-base. Wheel loads were increased from 800 to 1,000 pounds at 164,400 wheel-trips.

TABLE 4.—*Schedule of operations and behavior of test sections*

Operation	Traffic	Water level above top of sub-base	Behavior					
			Sec. 1	Sec. 2	Sec. 3	Sec. 4	Sec. 5	Sec. 6
	Wheel-trips	*Inches*						
Placing and compacting	0–20, 000	[1] 0	Good	Good	Good	Good	Good	Good.
Compacting treated surface	20, 000–40, 000	[1] 0	do	do	do	do	do	Do.
Testing with concentrated traffic	40, 000–40, 572	½	do	do	do	Failed	do	Do.
Compacting treated surface on dummy sec. 4 with distributed traffic.	40, 572–44, 972	[1] 0	do	do	do		do	Do.
Testing with concentrated traffic	44, 972–84, 400	½	Unstable	do	do		Slightly unstable	Do.
Do	84, 400–124, 400	2½	Failed	do	Slightly unstable		do	Do.
Do	[2] 124, 400–180, 720	4½		do	Unstable		Failed	Slightly unstable.[3]

[1] No water in sub-base.
[2] Wheel loads increased from 800 pounds to 1,000 pounds at 164,400 wheel-trips.
[3] A soft spot developed in sec. 6 during the last phase of testing which rapidly became deeper. The remainder of the section remained good. See figure 4.

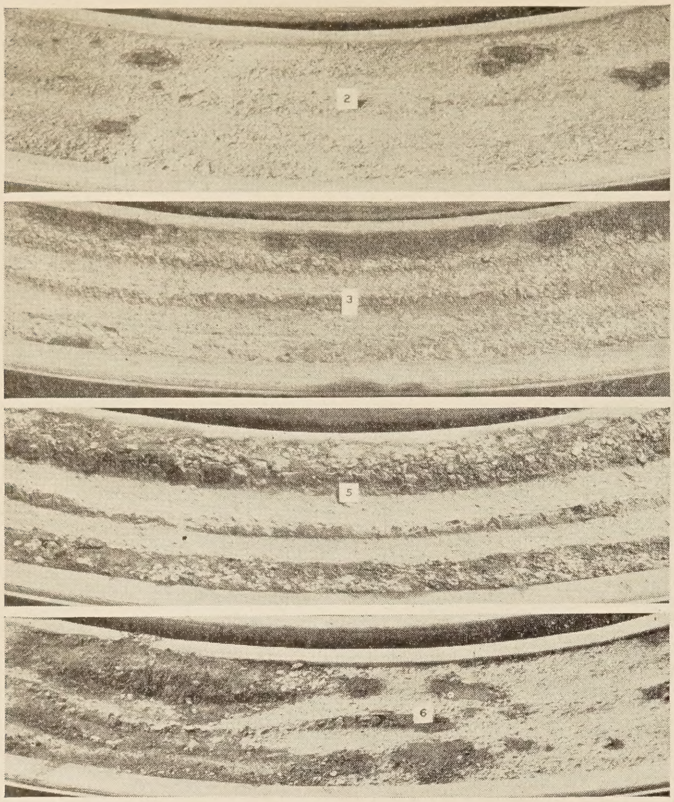

FIGURE 4.—APPEARANCE OF SECTIONS 2, 3, 5, AND 6 AT THE END OF TEST. NOTE THE SOFT SPOT THAT DEVELOPED IN SECTION 6.

At the end of this very severe treatment, section 5 had failed completely and section 3 was unstable and in very poor condition. Figure 4 shows the condition of these two sections at 180,720 wheel-trips, when testing was discontinued.

A soft spot developed in section 6, composed of chert C with 5 percent hydrated lime, at about 160,000 wheel-trips. Mud and water began to work through the surface treatment but excessive displacements were not observed. However, when the wheel loads were increased at 164,400 wheel-trips a localized failure developed at this spot on section 6. The rest of the section remained in good condition throughout the test.

The appearance of section 6 at the end of testing is shown in figure 4. The soft spot can be seen at the left.

Section 2, composed of sand, chert A, and 5 percent hydrated lime, remained in good condition at all times during the testing. The average vertical displacement on this section at the end of the test was only 0.05 inch, and average depth of ruts at the same time about 0.09 inch. The condition of section 2 at the conclusion of testing is shown in figure 4.

The density of each track section was measured at the time of failure or at the end of the testing period. The results of these determinations are shown in table 5, together with the densities obtained in the standard compaction test performed on the fraction of the material passing the No. 4 sieve.

Laboratory compaction tests were also made on the materials as tested in the track. The procedure for making these tests was similar to the standard test, except that a mold having a capacity of one-fourth cubic foot was used and the soil was compacted in three layers with 100 blows of the standard rammer per layer. The results of these tests are also shown in table 5.

TABLE 5.—*Comparison of densities obtained by laboratory compaction tests and by testing in the circular track*

Method of compaction	Section No.	Water content based on dry weight	Composition by volume		
			Water	Aggregate	Air voids
		Percent	*Percent*	*Percent*	*Percent*
Standard compaction test on fraction passing No. 4 sieve	1	11.6	23.0	72.2	4.8
	2	14.0	25.9	67.1	7.0
	3	14.6	28.2	70.2	1.6
	4	16.1	27.6	62.3	10.1
	5	19.6	31.1	57.8	11.1
	6	15.8	28.1	64.6	7.3
Compaction test on entire sample in ¼ cubic foot mold	1	13.3	26.3	71.9	1.8
	2	15.0	29.2	70.8	0
	3	14.1	26.9	69.3	3.8
	4	14.0	24.9	64.7	10.4
	5	18.0	31.0	62.7	6.3
	6	13.8	26.2	69.1	4.7
Samples cut from track at end of test or time of failure	1	9.9	20.2	74.0	5.8
	2	14.6	26.0	64.7	9.3
	3	12.3	24.0	71.0	5.0
	4	15.1	26.5	63.9	9.6
	5	19.0	32.7	62.6	4.7
	6	16.7	29.0	63.2	7.8

The addition of 5 percent hydrated lime reduced the densities of both the sand-chert A mixture and chert B in the track sections as well as in the laboratory compaction tests. Thus the amount of aggregate solids by volume for the section 1 materials in the standard compaction test was 72.2 percent; in the compaction test in the ¼ cubic foot mold, 71.9 percent; and in the track, 74.0 percent. Corresponding aggregate volumes for the section 2 materials, which were similar to section 1 except for the addition of 5 percent hydrated lime were, respectively, 67.1 percent, 70.8 percent, and 64.7 percent. Similarly, the densities of the section 5 materials, chert B with 5 percent hydrated lime, were consistently lower than the corresponding densities of the section 4 material, which was chert B without admixture.

No consistent relationship was found between densities measured by either of the laboratory compaction methods and those obtained in the track. The closest agreement was between the track densities and densities obtained by the standard compaction test.

In sections 1, 3, and 4, where hydrated lime was not used, the track densities were higher than those obtained in the standard compaction test. In sections 2 and 6, where lime was used, the reverse was true. In section 5, which also contained lime, the track densities were the higher.

SUMMARY

The grading curves for the six combinations of materials tested are shown in figure 5. The shaded band in this figure is drawn to include the A. A. S. H. O. specification requirements for coarse-graded-type aggregate base-course materials having a maximum size of 1 inch. The curve for the section 6 material is the only one which falls entirely within the specification limits. These specifications further stipulate that the fraction passing the No. 40 sieve shall have a liquid limit not greater than 25 and a plasticity index not greater than 6. All mixtures tested in the track had plasticity indexes of less than 6 except that used in section 1. The liquid limits of the materials used in sections 2, 5, and 6 exceeded 25 (see table 1). All three of these sections,

(Continued on page 80)

BENDING TESTS ON BITUMINOUS MIXTURES

BY THE DIVISION OF TESTS, PUBLIC ROADS ADMINISTRATION

Reported by W. O'B. HILLMAN, Assistant Highway Engineer

BENDING TESTS on bituminous paving mixtures have been made for some time. In 1923 and 1924 the Public Roads Administration made a series of such tests, the results of which were not published, which seemed to indicate some relationship between stiffness of the mixture and cracking of the pavement in service. Bituminous surfaces that had cracked in service were generally found to consist of stiffer mixes, as determined by bending tests, than those which had not cracked. These tests were made at 32° F. and 77° F. using a small universal testing machine to apply a center load on a 2-inch by 2-inch beam with a span of 10 inches.

Recently Professor Lloyd F. Rader,[1 2 3 4] of Brooklyn Polytechnic Institute, made bending tests upon sheet asphalt mixtures at temperatures as low as −70° F., cooling the specimens with dry ice. He used beams 2 inches wide and 1½ inches deep with a span of 6 inches. A center load was applied with a testing machine. Both laboratory prepared specimens and specimens cut from pavements were tested. Rader studied the effect of temperature, degree of compaction, type of asphalt, and percentage of asphalt, upon the test results. At the lowest temperatures straight load-deflection curves were obtained but at higher temperatures they were considerably curved. The modulus of rupture and the modulus of elasticity were calculated. On the field specimens Rader found that in general the uncracked pavements had higher moduli of rupture and lower moduli of elasticity than the cracked pavements.

Raschig and Doyle [5 6] have also made bending tests on laboratory prepared specimens and specimens taken from pavements. These beam specimens were 1.5 inches square, tested as cantilevers with lengths of 4 inches. Tests were made at −5, 25, and 38° F. and the modulus of elasticity and modulus of rupture were calculated.

SPECIAL BEAM TESTING MACHINE DESIGNED AND BUILT

These previous investigations have indicated the possible value of the flexure test as a means for studying the essential characteristics of bituminous paving mixtures and the reasons for the variable behavior of bituminous pavements. This investigation was undertaken primarily to study the effect of different variables upon the test results obtained with laboratory specimens although, as a matter of interest, some data from tests on samples taken from pavements are included in the report.

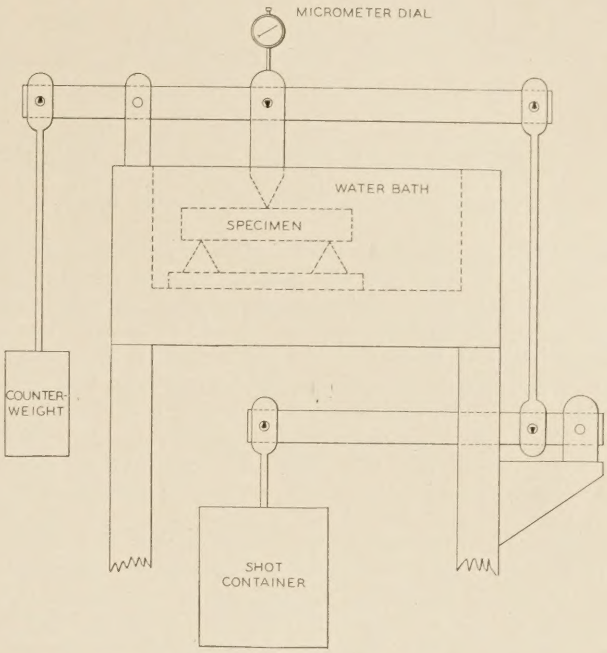

FIGURE 1.—DIAGRAMMATIC SKETCH OF BENDING APPARATUS.

Bituminous paving mixtures are plastics and therefore the results of bending tests on them depend to a great degree on the rate at which loads are applied. Since a testing machine that would apply the load smoothly and at a uniform rate, and still be sensitive in the low range of load necessary, was not available, it was necessary to design and build a special machine for making these tests. A sketch of this machine is given in figure 1 and a general view on the cover page of this issue.

It consists of two beam supports which can be adjusted for spans of 6, 8, and 10 inches, and a multiplying lever arrangement for applying a load at the center by means of lead shot. A water bath is used so that the specimen can be maintained at a definite temperature during the testing operation. Deflections are measured with an Ames dial which measures the travel of the top lever. Specimens as large as 3 inches by 3 inches can be tested. The rate of load application can be varied from about 75 pounds per minute to about 500 pounds per minute.

A limited number of tests have been made so far primarily to try out the apparatus, determine the effect of controllable variables upon the test results, and decide upon a standard method of test. Laboratory specimens were made of Potomac River sand, limestone dust, and 50-penetration Mexican asphalt. In order to reduce as much as possible the hardening of the asphalt during the fabrication of the specimens, only sufficient mixture to make one beam was prepared at a time. Beams were formed in a 2-inch by 11-inch mold by direct compression of 3,000 pounds per square inch

[1] Investigations of the Physical Properties of Asphaltic Mixtures at Low Temperatures, Proceedings of the Association of Asphalt Paving Technologists, January 1935.
[2] Investigations of the Physical Properties of Asphaltic Mixtures at Low Temperatures, Proceedings of the American Society for Testing Materials, 1935.
[3] Correlation of Low Temperature Tests with Resistance to Cracking of Sheet Asphalt Pavements. Proceedings of the Association of Asphalt Paving Technologists, January 1936.
[4] Report on Further Research Work on Correlation of Low Temperature Tests with Resistance to Cracking of Sheet Asphalt Pavements. Proceedings of the Association of Asphalt Paving Technologists, January 1937.
[5] Some Recent Research on Asphalt Pavement. Proceedings of the Association of Asphalt Paving Technologists, January 1937.
[6] An Extension of Asphalt Research as Reported in the 1937 Proceedings. Proceedings of the Association of Asphalt Paving Technologists, December 1937.

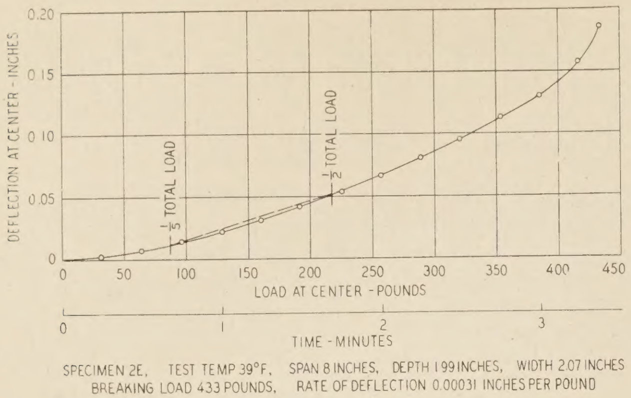

FIGURE 2.—TYPICAL LOAD-DEFLECTION CURVE.

using two opposed plungers. The thickness was controlled by the amount of material placed in the mold.

On the day following molding of the specimens they were tested for specific gravity and then brought to test temperature by immersion in a water bath for 1½ hours. They were then placed in the test apparatus with plates ½ inch wide between the beam and the knife edges to keep the knife edges from indenting the beams. Loading was started and the Ames dial read at convenient time intervals until the beam broke. As the shot flows at a uniform rate, the load is proportional to the time and the load-deflection curves were plotted as in figure 2.

It is customary in reporting the results of bending tests to use the modulus of rupture as a measure of the strength of the material and the modulus of elasticity as a measure of the stiffness. The modulus of rupture was calculated from the formula

$$S=\frac{3Pl}{2bd^2}$$

where S = the modulus of rupture in pounds per square inch;
P = the breaking load;
l = the span in inches;
b = the width of the beam; and
d = the depth of the beam.

None of the load-deflection curves was straight and it was necessary to calculate a secant modulus of elasticity. Because of difficulty in correctly ascertaining the initial dial reading, only the portion of the curve between one-fifth and one-half the breaking load was used. The formula for modulus of elasticity then became

$$E=\frac{l^3}{4bd^3R}$$

where E = the modulus of elasticity in pounds per square inch;
R = the average rate of deflection in inches per pound of load; and
l, b, and d are the same as in the formula for modulus of rupture.

RATE OF LOADING AFFECTED MODULI OF RUPTURE AND ELASTICITY

Tests were first made to determine the effect of changing the rate of loading upon the test results. Identical beams were tested at 39° F. using three different rates of loading. The results, plotted in figure 3, show that increasing the rate of loading increases the modulus of rupture and the modulus of elasticity.

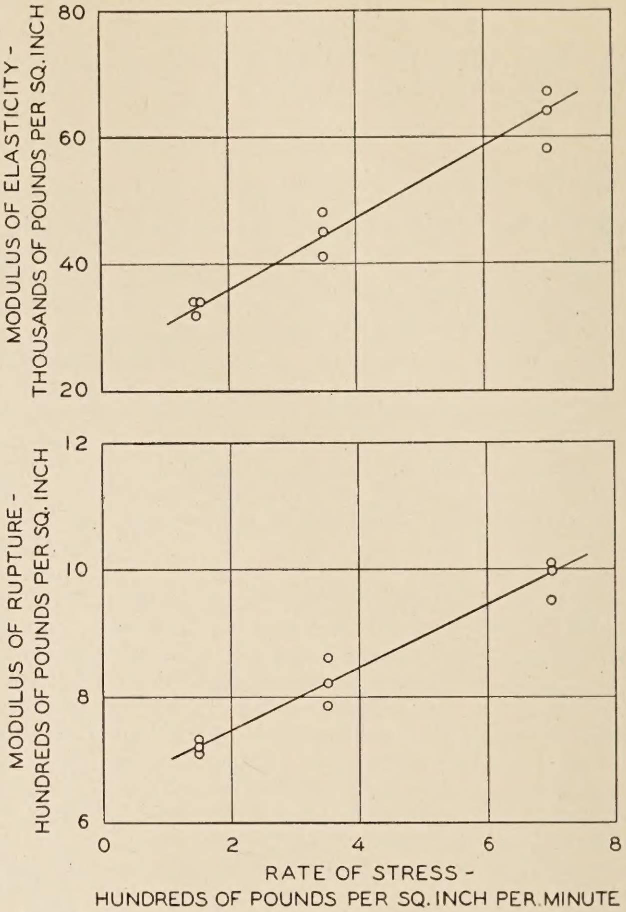

FIGURE 3.—EFFECT OF CHANGING RATE OF LOADING UPON THE TEST RESULTS.

In connection with the tests to determine the effect of rate of loading, a few beams were tested with constant loads. Time-deflection curves for these beams are shown in figure 4, together with the curve for a beam tested in the usual manner. It required almost 4 minutes and a load of 485 pounds to break the beam when the load increased at the rate of 125 pounds per minute. However, a constant load of 353 pounds, less than ¾ of the increasing load, broke the beam in less than 3 minutes. Loads of 295 and 235 pounds broke the beams in about 5 and 13 minutes, respectively.

Tests were made to determine the validity of the formulas for modulus of rupture and modulus of elasticity when applied to bituminous beams by testing beams of the same composition but of various dimensions and with various spans. Because of the great difference in test results obtained with different rates of loading, it was necessary to assume that the modulus of rupture formula was applicable and to vary the rate of loading directly as the width of the beam, directly as the square of the depth of the beam, and inversely as the test span. The rate of stress, calculated from the modulus of rupture formula, would thus be a constant.

Specimens 1, 1½, and 2 inches deep were made. For testing beams of different widths these were turned on edge to give beams 2, 1½, and 1 inch wide and 2 inches deep. These were tested on a span of 8 inches, the loads being applied at the rate of 120 pounds per inch width per minute. The results, given in table 1, show that beams of different widths but of the same depth when tested on the same span have practically the same modulus of rupture and modulus of elasticity.

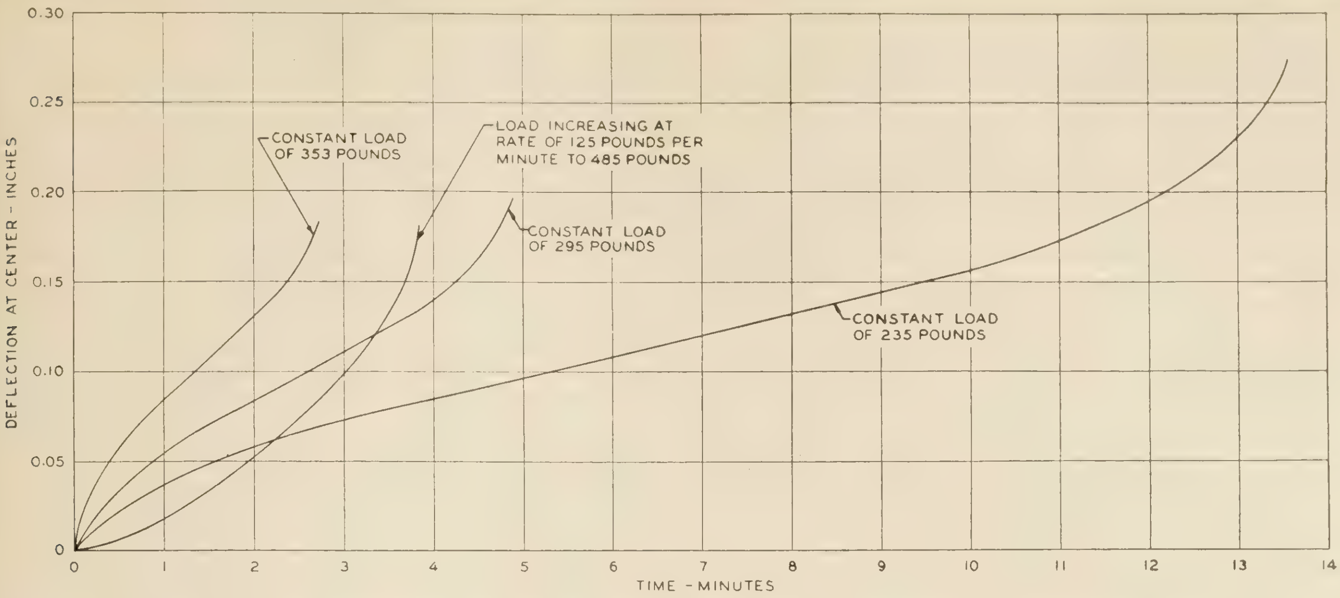

FIGURE 4.—TIME-DEFLECTION CURVES FOR BEAMS SUBJECTED TO CONSTANT AND INCREASING LOADS.

The results of tests on beams with various depths and test spans are given in table 2. In order to show the amount of variation among the individual tests all the results are given. For the sizes of beams used in these tests the depth and test span do not appear to affect greatly the value of the modulus of rupture. The short, deep beams, however, have lower values for modulus of elasticity than have the longer and thinner beams. Part, if not all, of this variation in modulus of elasticity is probably caused by assuming that all the deflection is caused by bending stresses, whereas with deep beams of short spans a considerable amount of deflection is caused by shearing stresses.

Figure 5 shows that increasing the density of the specimens by greater compaction increases both their strength and stiffness.

TABLE 1.—*Effect of width of test specimen on the results of bending tests at 39° F.*

Width of specimen	Modulus of rupture	Modulus of elasticity
Inches	*Lb. per sq. in.*	*Lb. per sq. in.*
2.0	660	32,000
1.5	690	32,000
1.0	630	35,000

Figures 6 and 7 show the effect of temperature upon the test results. Temperatures as low as 0° F. were obtained using mixtures of ice, salt, and water. The temperature of −27° F., shown in figure 7, was obtained in a refrigerator. The specimens were kept in the refrigerator for 3 hours and then tested, the bath of the testing apparatus being filled with ice, salt, and water at 0° F. Because of the large amount of ice required to obtain temperatures below 39° F. it was difficult to place the specimens correctly in position for testing. The results, therefore, are not as consistent as they are at temperatures of 39° F. and higher. Nevertheless, they do show in a general way how a reduction in temperature increases the strength and stiffness of a mixture.

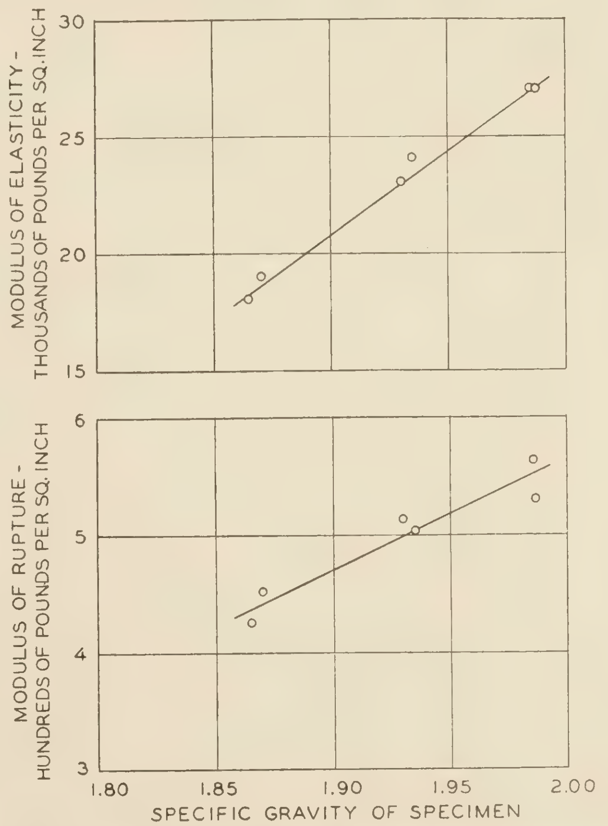

FIGURE 5.—EFFECT OF VARIATIONS IN DENSITY UPON MODULUS OF RUPTURE AND MODULUS OF ELASTICITY OF SPECIMENS.

EFFECT OF COMPOSITION ON BEAM STRENGTH INVESTIGATED

Mixtures were made with four different percentages of asphalt and four different ratios of sand and filler. All specimens were 2 inches deep molded under a pressure of 3,000 pounds per square inch. Specimens were tested at 39° F. with a span of 8 inches, applying the load at 120 pounds per minute, which gave a rate of stress of 180 pounds per square inch per minute. Results are given in table 3 and in figures 8, 9, and 10.

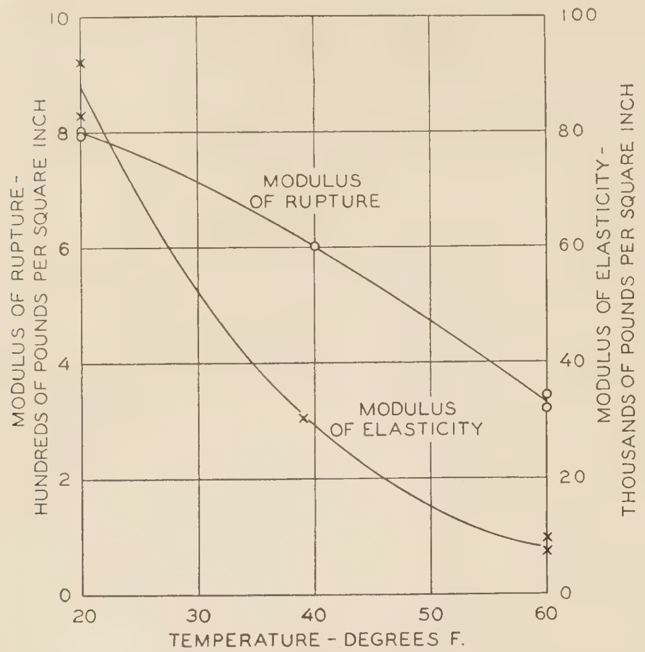

FIGURE 6.—EFFECT OF TEMPERATURE UPON MODULUS OF RUPTURE AND MODULUS OF ELASTICITY OF SPECIMENS.

TABLE 2.—*Effect of beam dimensions on the results of bending tests at 39 ° F. when the rate of stress*[1] *was 550 pounds per square inch per minute*

Span	Depth					
	1 inch		1½ inches		2 inches	
	Modulus of rupture	Modulus of elasticity	Modulus of rupture	Modulus of elasticity	Modulus of rupture	Modulus of elasticity
	Lb. per sq. in.	*Lb. per sq. in.*	*Lb. per sq. in.*	*Lb. per sq. in.*	*Lb. per sq. in.*	*Lb. per sq. in.*
6 inches	688	51, 000	683	36, 000	774	34, 000
	611	39, 000	720	32, 000	771	34, 000
	712	45, 000	790	46, 000	756	----------
	768	47, 000	740	46, 000	844	48, 000
	702	----------	818	50, 000	816	33, 000
	896	60, 000	878	50, 000	864	42, 000
	762	52, 000	818	34, 000	764	33, 000
	820	56, 000	806	36, 000	792	33, 000
Average	745	50, 000	782	41, 000	797	37, 000
8 inches	765	56, 000	762	50, 000	781	50, 000
	803	66, 000	755	63, 000	823	57, 000
	795	73, 000	815	66, 000	832	53, 000
	765	63, 000	809	61, 000	754	45, 000
Average	782	64, 000	785	60, 000	798	52, 000
10 inches	714	50, 000	683	61, 000	739	54, 000
	721	50, 000	693	59, 000	828	62, 000
	787	82, 000	784	62, 000	756	54, 000
	758	70, 000	758	62, 000	758	54, 000
Average	745	63, 000	730	61, 000	770	56, 000

[1] The rate of stress is the modulus of rupture divided by the time required to break the beam.

For mixtures containing 0, 5, and 10 percent dust the modulus of rupture increased with increasing amounts of asphalt up to 14 percent, but for mixtures containing 15 percent dust the maximum modulus of rupture was obtained with 12 percent asphalt.

Figure 9 shows the composition of the specimens by volume and indicates why the modulus of rupture decreased when the mixture contained 14 percent asphalt with 15 percent filler in the aggregate. With 0, 5, and 10 percent filler in the aggregate the increase of asphalt from 8 to 14 percent increased the percentage of aggregate in the specimen. With 15 percent filler in the aggregate the percentage of aggregate by volume increased at a uniform rate with increases in asphalt up to 12 percent, but with 14 percent asphalt the percentage of the aggregate was decreased.

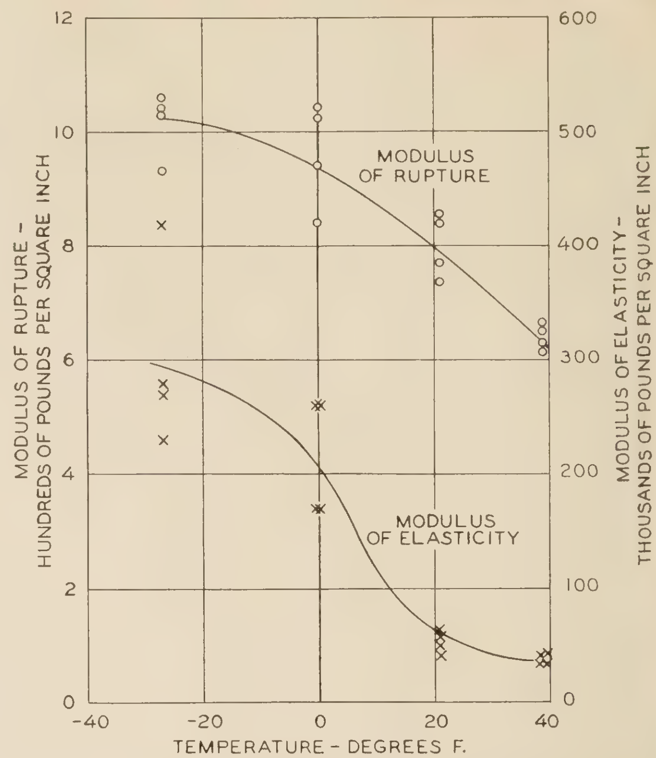

FIGURE 7.—EFFECT OF TEMPERATURE UPON MODULUS OF RUPTURE AND MODULUS OF ELASTICITY OF SPECIMENS.

TABLE 3.—*Results of bending tests on specimens*[1] *made with various amounts of asphalt and filler*

	Percentage of asphalt	Percentage of filler in aggregate			
		0	5	10	15
Modulus of rupture......lb. per sq. in..	8	385	450	490	570
Modulus of elasticity..........do....		20, 000	26, 000	31, 000	38. 000
Total deflection..........inches..		0. 185	0. 170	0. 140	0. 130
Modulus of rupture......lb. per sq. in..	10	465	555	600	710
Modulus of elasticity..........do....		22. 000	26, 000	31, 000	44, 000
Total deflection..........inches..		0. 190	0. 190	0. 165	0. 140
Modulus of rupture......lb. per sq. in..	12	555	650	780	915
Modulus of elasticity..........do....		22, 000	28, 000	35, 000	43, 000
Total deflection..........inches..		0. 240	0. 220	0. 190	0. 190
Modulus of rupture......lb. per sq. in..	14	785	865	895	850
Modulus of elasticity..........do....		24, 000	25, 000	25, 000	22, 000
Total deflection..........inches..		0. 300	0. 330	0. 330	0. 330

[1] 2-inch by 2-inch specimens tested with span of 8 inches. Test temperature, 39° F. Rate of stress, 180 pounds per square inch per minute.

Figure 10 shows the modulus of elasticity and the total deflection of the various mixtures. There is little consistent difference between the moduli of elasticity of the specimens containing, 8, 10, and 12 percent asphalt. All became stiffer as the amount of dust was increased. As the strengths of the specimens increased with increasing asphalt contents, the total deflections increased likewise although the moduli of elasticity were about the same. With 14 percent asphalt the modulus of elasticity was about the same for 0, 5, and 10 percent dust but decreased with 15 percent dust. With 10 and 15 percent dust the modulus of elasticity was much lower than that of specimens containing 8, 10, and 12 percent asphalt. The total deflection of the specimens containing 14 percent asphalt was much greater than the deflection of the specimens containing less asphalt.

TABLE 4.—*Results of bending tests on various types of surfaces*[1] *from Ohio projects*

Specimen No.	Type of surface	Age	Condition of surface	Rate of stress	Modulus of rupture	Modulus of elasticity
		Years		*Lb. per sq. in. per min.*	*Lb. per sq. in.*	*Lb. per sq. in.*
43309-1	Sheet asphalt on binder course.		Good	141	962	36,000
43309-2				143	1,040	37,000
43309-3				145	1,037	40,000
Average					1,015	38,000
43319-1	Two-course bituminous concrete.	1½	Excellent	145	880	84,000
43319-2				149	960	92,000
43319-3				145	840	92,000
Average					895	89,000
43321-1	do	4+	Good	138	818	61,000
43321-2				139	910	105,000
43321-3				139	854	101,000
Average					860	89,000
43322-1	do	2½	Excellent	228	850	83,000
43322-2				262	812	103,000
Average					830	93,000
43306-1	do	3+	Good	150	724	92,000
43306-2				140	718	103,000
43306-3				144	852	100,000
43306-4				135	902	96,000
Average					800	98,000
43320-1	do	4+	Generally cracked.	143	712	82,000
43320-2				145	738	137,000
43320-3				142	704	108,000
Average					720	109,000
43318-1	do	4+	do	136	648	56,000
43318-2				142	668	40,000
Average					660	48,000
43311-1	Sheet asphalt on binder course.	6½	do	140	524	24,000
43311-2				142	620	84,000
43311-3				142	617	96,000
43311-4				140	554	94,000
Average					580	75,000
43304-1	Two-course bituminous concrete.	3+	Badly cracked and worn.	140	489	112,000
43304-2				142	577	76,000
43304-3				140	632	102,000
43304-4				143	520	103,000
Average					555	98,000
43326-1	do	5½	Badly cracked	140	520	103,000
43326-2				142	566	80,000
43326-3				141	576	105,000
43326-4				140	505	56,000
Average					540	86,000
43323T-1	Bituminous concrete.	2+	Good	140	536	78,000
43323T-2				143	454	90,000
Average					495	84,000
43323B-1	Bituminous concrete (base for above).			177	580	100,000
43323B-2				161	448	100,000
Average					515	100,000
43316-1	Two-course bituminous concrete.	3½	Badly cracked and ravelled.	141	462	102,000
43316-2				145	335	153,000
43316-3				141	522	161,000
43316-4				140	475	115,000
Average					450	133,000

[1] Tested at 39° F. Span, 6 inches.

In order to obtain information about the characteristics of actual pavements when tested in this manner, samples were obtained from several pavements in Ohio and Wisconsin and from one pavement in the District of Columbia.

The samples from Ohio were representative of several types of bituminous surfacing. The specimens were 2 inches wide and 2 inches deep. Each specimen contained all of the top course and a portion of the base

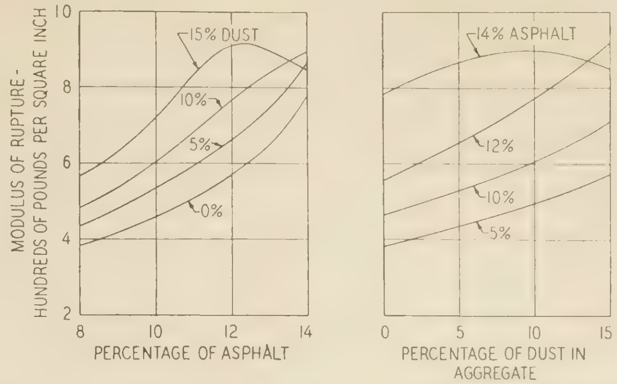

FIGURE 8.—EFFECT OF COMPOSITION UPON THE MODULUS OF RUPTURE.

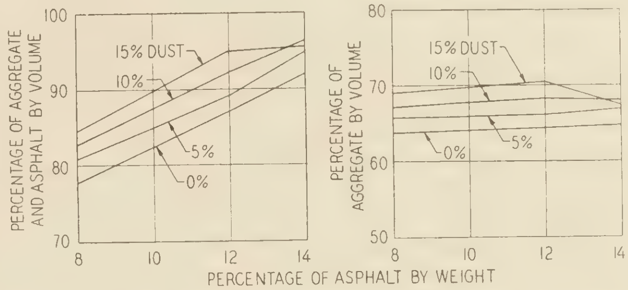

FIGURE 9.—COMPARISON OF WEIGHT AND VOLUME COMPOSITION OF BEAMS.

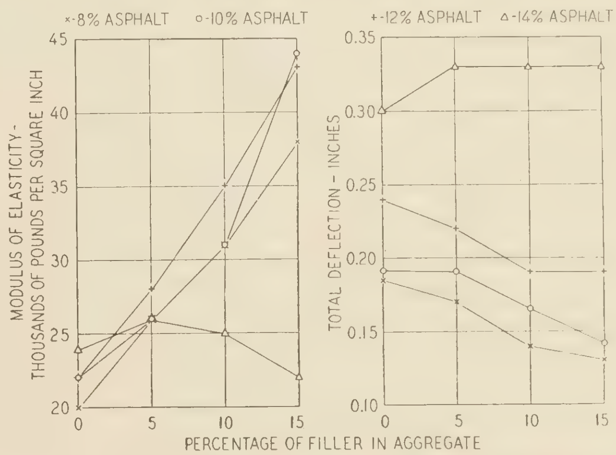

FIGURE 10.—EFFECT OF COMPOSITION UPON MODULUS OF ELASTICITY AND TOTAL DEFLECTION.

course. They were tested at 39° F. on a span of 6 inches with the wearing surface in tension. The results are given in table 4. Samples are arranged in order of strength. It is, of course, difficult to correlate laboratory results with field behavior as there are so many unknown factors contributing to the failure of a surface. All of the pavement samples were taken from locations where the base was in good condition. Generally, the good pavements had the highest modulus of rupture but there seems to be little correlation between the modulus of elasticity and the condition of the pavement.

The samples from Wisconsin and the District of Columbia were of sheet asphalt and in most cases the binder course was sawed off before testing. These specimens were 2 inches wide and slightly over 1 inch thick. A few samples were tested with enough of the

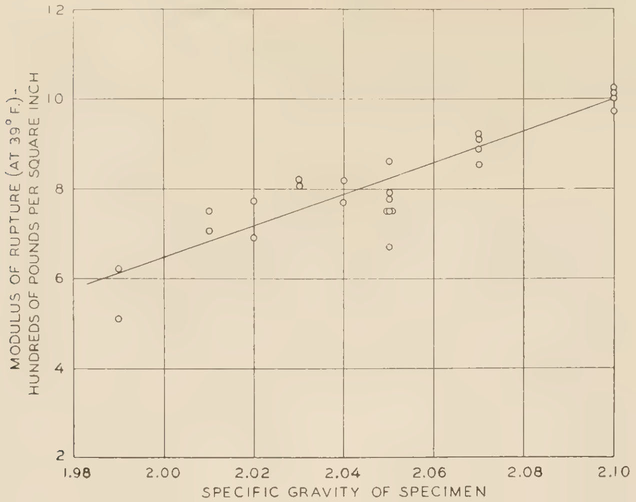

Figure 11.—Effect of Density Upon the Modulus of Rupture of Sheet Asphalt From Connecticut Ave., District of Columbia.

binder course to make specimens 2 inches deep. All specimens were tested at 39° F. on a span of 6 inches with the wearing surface in tension. Results of these tests are given in tables 5, 6, and 7.

The samples from the District of Columbia were taken immediately after the pavement had been laid. They were all the same composition, varying only in density, and it is seen in figure 11 that there is a direct relationship between the density and strength of the specimens. Comparing tables 5 and 6 it is seen that for the 2-inch specimens the modulus of rupture is somewhat lower and the modulus of elasticity considerably lower than for the 1-inch specimens. A great part of this difference is caused by the difference in the rate of stress during the two tests. The pavement from which these samples were taken was in good condition in September 1939 after 3½ years service.

All of the Wisconsin samples were from pavements in good condition. Differences in composition account for the differences in strength and stiffness.

Table 5.—*Results of bending tests on samples [1] of sheet asphalt from Connecticut Ave., Washington, D. C.*

Section No.	Specific gravity	Modulus of rupture	Total deflection	Modulus of elasticity
		Lb. per sq. in	*Inches*	*Lb. per sq. in.*
A-1	1.99	619	0.090	65,000
		514	.060	68,000
A-2	2.05	777	.095	67,000
		671	.070	95,000
C-1	2.02	774	.100	49,000
		688	.090	61,000
	2.04	813	.090	76,000
		770	.095	65,000
C-2	2.05	753	.095	68,000
		791	.090	68,000
		752	.075	80,000
		862	.080	83,000
D-1	2.07	887	.120	62,000
		917	.105	70,000
		912	.115	77,000
		856	.110	64,000
D-2	2.10	968	.100	72,000
		1,015	.090	84,000
		1,010	.100	82,000
		1,016	.095	82,000
D-3	2.01	749	.100	6[illegible],000
		706	.080	66,000
	2.03	805	.110	62,000
		820	.090	83,000

[1] Top course only, 1.1 to 1.2 inches thick, 2 inches wide. Tested at 39° F. Span, 6 inches. Rate of stress, 425 pounds per square inch per minute.

Table 6.—*Results of bending tests on samples [1] of sheet asphalt from Connecticut Ave., Washington, D. C.*

Section No.	Specific gravity	Modulus of rupture	Total deflection	Modulus of elasticity
		Lb. per sq. in.	*Inches*	*Lb. per sq. in.*
C-1	2.16	778	0.080	48,000
	2.16	758	.090	41,000
C-2	2.17	747	.085	39,000
	2.17	792	.080	44,000
D-1	2.14	721	.095	34,000
D-2	2.15	882	.100	35,000
D-3	2.12	618	.080	37,000

[1] Top and binder course sawed to thickness of 2 inches. Tested at 39° F. Span, 6 inches. Rate of stress, 150 pounds per square inch per minute.

Table 7.—*Results of bending tests on samples [1] of sheet asphalt from Wisconsin*

Specimen No.	Rate of stress	Modulus of rupture	Total deflection	Modulus of elasticity
	Lb. per sq. in. per min.	*Lb. per sq. in.*	*Inches*	*Lb. per sq. in.*
43331	450	1,125	0.060	128,000
	465	1,220	.075	96,000
43332	460	1,069	----	120,000
	455	1,308	.075	110,000
43335	420	1,039	.055	119,000
	420	1,034	.055	117,000
43341	435	1,142	----	138,000
43342	490	1,244	.110	98,000
	490	1,233	.120	98,000
43343	480	1,039	.090	103,000
	480	1,120	.090	109,000
43333	425	1,094	.105	70,000
	425	1,117	.080	80,000
3334	445	1,142	.080	101,000
43344	470	1,174	.110	77,000
43345	470	1,116	.125	74,000
43346	470	1,105	.075	106,000
	485	1,183	.090	106,000
43347	465	1,130	.105	88,000
	430	1,106	.095	78,000
43336	465	1,020	.150	66,000
	445	983	.140	63,000
43337	430	891	.115	65,000
43338	430	888	.100	77,000
	465	1,004	.115	86,000
43339	430	944	.160	58,000
	420	939	.170	55,000
43340	465	990	.120	87,000

[1] Top course only, 1.1 to 1.2 inches thick. Tested at 39° F. Span, 6 inches.

These results of tests on actual surfaces are reported only as an indication of the possibilities of this type of investigation.

SUMMARY

These flexure tests of bituminous mixtures with a constant rate of loading show that the modulus of rupture and the modulus of elasticity both increase as the rate of stress increases.

With a constant rate of stress it is indicated:

1. That the value of the modulus of rupture is not greatly influenced by the ratio of span length to depth of the test specimen.

2. That for a given span length the value of the modulus of elasticity decreases as the depth of beam increases and that for a given depth of beam the modulus increases as the span length is increased. In other words the modulus of elasticity decreases as the ratio of depth of beam to span length increases.

3. That the modulus of rupture and the modulus of elasticity, calculated by the usual formulas, are satisfactory measures of the strength and stiffness of bituminous mixtures when due consideration is given to the effect on the modulus of elasticity of the ratio of span length to depth of beam.

4. That increasing the density of specimens by increased compaction increases their strength and stiffness. (*Continued on p. 81*)

EFFECT OF CONSISTENCY AND TYPE OF ASPHALT ON THE HUBBARD-FIELD STABILITY OF SHEET ASPHALT MIXTURES

BY THE DIVISION OF TESTS, PUBLIC ROADS ADMINISTRATION

Reported by W. O'B. HILLMAN, Assistant Highway Engineer

BECAUSE the consistency of the contained asphalt affects the resistance of bituminous mixtures to displacement under traffic, it has been customary to vary somewhat the grade of asphalt depending on the climatic and traffic conditions. In general, the grades used in the Northern States are softer than those used in the Southern States for the same type of construction. In the same locality harder grades are used on the streets carrying the heavier traffic.

Recently, because of the great amount of cracking occurring in pavements, there has been a general trend towards the use of softer asphalts in sheet asphalt and asphaltic concrete construction. The effect of these softer grades of asphalt on the stability is, therefore, a matter of present interest. The work here described gives the results of Hubbard-Field stability tests [1] on a typical sheet asphalt aggregate mixed with various grades and types of asphalt.

The mixture was similar in composition to that currently used in the District of Columbia. It contained 78 percent Potomac River sand, 11 percent limestone dust, and 11 percent asphalt. The first series of tests were made with 10 different grades of Mexican asphalt ranging in penetration from 23 to 182. These asphalts were all made by the same producer using the same process of manufacture.

The penetrations of these asphalts were determined at a number of temperatures. The relations between penetration values and test temperatures are shown in figure 1.

As has already been shown [2] the slope of the log penetration-temperature curve is a measure of the temperature susceptibility of the asphalt. The greater the slope the more susceptible is the asphalt. The slope can be calculated as follows:

$$\text{Slope} = M = \frac{\log p_2 - \log p_1}{t_2 - t_1}$$

where p_2 and p_1 are penetrations at temperatures t_2 and t_1, respectively. For these Mexican asphalts the slope had a constant value of approximately 0.022.

By extending the curves upward, as represented by the dotted lines in figure 1, the penetration of the asphalts at any temperature may be estimated. Plotted on this dotted portion are the softening points of the asphalts. The penetration at the softening point averaged about 850 for these asphalts.

In order to minimize alteration of the asphalt during preparation of the specimens, the following method of fabrication, which previous work had shown to cause very little hardening of the asphalt, was followed. Sufficient sand and filler to make three specimens were combined at room temperature. The cold asphalt was added and the pan containing the combined materials placed on a hot plate. Mixing was accomplished by continuous stirring at the lowest possible temperature. The temperature of the finished mixtures ranged from about 220° F. for the 180-penetration asphalt to about 280° F. for the 23-penetration asphalt.

STABILITIES OF MEXICAN ASPHALTS DEPENDED UPON THEIR CONSISTENCIES

Two forming molds and two compression machines were used, and after mixing was completed two specimens were immediately compressed using a load of 3,000 pounds per square inch maintained for 2 minutes. As soon as the first two specimens had been compacted the mixture for the third specimen, which had been kept hot, was placed in the mold and compacted. Thus only about 4 minutes elapsed between the completion of mixing and the completion of molding. There was found to be no difference in the density or the stability of the three specimens comprising a set.

The specimens were tested for Hubbard-Field stability at 122° and 140° F. The results are given in table 1, together with the softening point and penetration of the asphalt and the estimated penetration of the asphalt at 140° and 122° F. When the logarithm of the stability is plotted against the logarithm of the penetration at 77° F. of the contained asphalt, as in figure 2, all points fall approximately on two parallel straight lines, one for a test temperature of 140° F. and the other for a test temperature of 122° F.

For these Mexican asphalts doubling the penetration of the asphalt reduced the Hubbard-Field stability of the sheet asphalt mixture by about 25 percent.

When the logarithm of the stability at either 122° or 140° F. is plotted against the logarithm of the penetration of the asphalt at the same test temperature, as in figure 3, all points fall approximately on the same straight line. Thus for asphalts from the same source and of the same type, the stability is dependent only upon the consistency of the asphalt at the test temperature.

With materials such as these, all of which are equally susceptible to temperature and have approximately the same consistency at their softening points, the softening point is a measure of consistency.

When the logarithm of the stability is plotted against the softening point of the contained asphalt (fig. 4), all points fall approximately on two parallel straight lines, one for stability at 140° F. and the other for stability at 122° F.

All of these asphalts had approximately the same consistency at their softening points. Because they were

[1] A Practical Method for Determining the Relative Stability of Fine-Aggregate Asphalt Paving Mixtures, by Prevost Hubbard and F. C. Field. Proceedings, American Society for Testing Materials, vol. 25, pt. II, p. 335 (1925).
A Study of Certain Factors Affecting the Stability of Asphalt Paving Mixtures, by Prevost Hubbard and F. C. Field. Proceedings, American Society for Testing Materials, vol. 26, pt. II, p. 577 (1926).

[2] The Physical and Chemical Properties of Petroleum Asphalts of the 50-60 and 85-100 Penetration Grades. R. H. Lewis and J. Y. Welborn. PUBLIC ROADS, vol. 21, No. 1, March 1940.

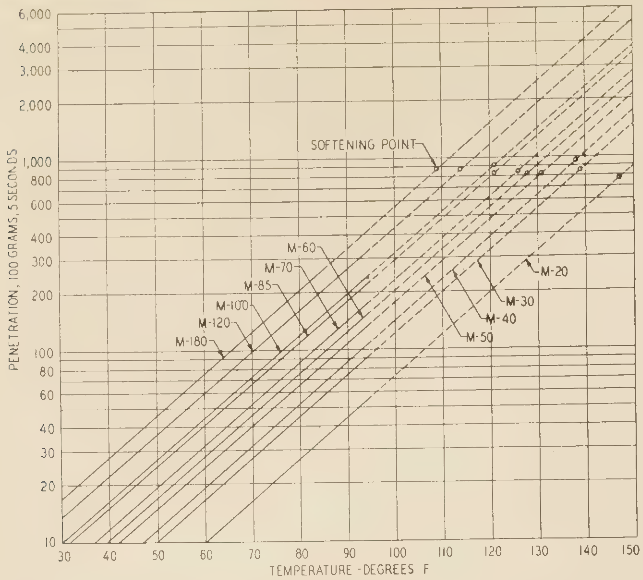

FIGURE 1.—RELATION BETWEEN TEMPERATURE AND PENETRATION FOR THE MEXICAN ASPHALTS USED.

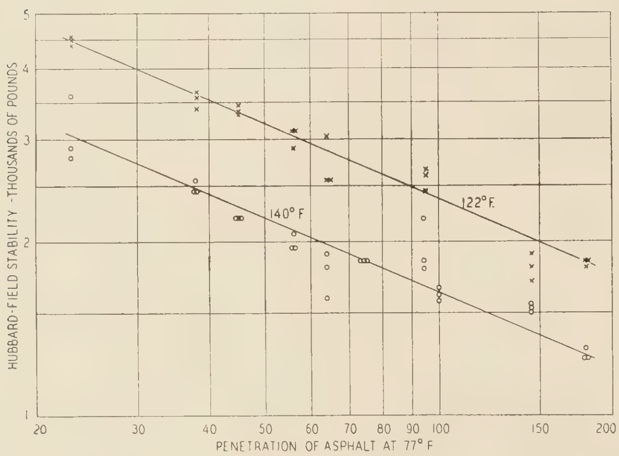

FIGURE 2.—RELATION BETWEEN HUBBARD-FIELD STABILITY AT 122° F. AND 140° F. AND THE PENETRATION AT 77° F., OF THE CONTAINED MEXICAN ASPHALT.

equally susceptible to changes in temperature they would have approximately the same penetration at temperatures that are above or below their respective softening points by equal amounts. When the penetration test temperature is subtracted from the softening point, asphalts having the same difference have the same consistency, and mixtures made from them have approximately the same stability, as shown in figure 5. This figure also shows that for these Mexican asphalts and these proportions, increasing the temperature of the stability test by 10° F. decreases the stability by about 20 percent.

In order to determine whether or not asphalts from other sources behaved in the same manner, a second series of specimens was made using two grades of petroleum asphalt from each of five different producers. The characteristics of these asphalts are given in table 2. The specimens were tested for stability at 104°, 122°, and 140° F., the results being given in table 3.

In figure 6 the stabilities of these mixtures at all three temperatures are plotted against the penetrations of the asphalts at 77° F. Asphalts from each producer are plotted separately.

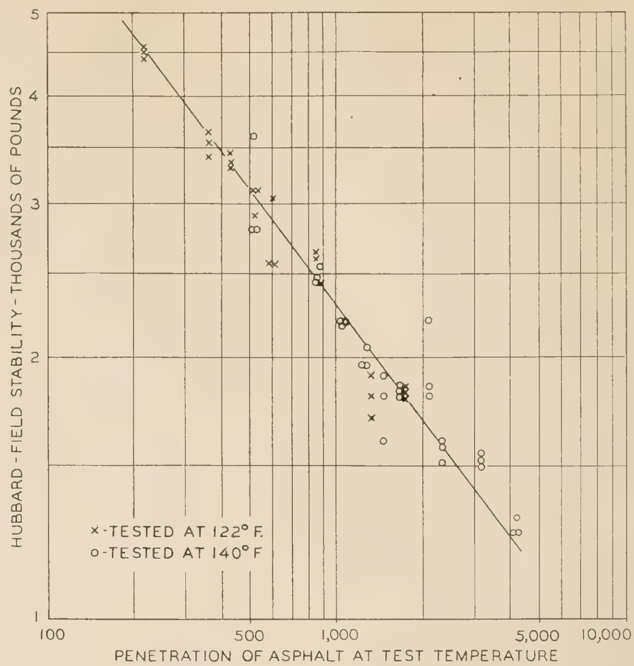

FIGURE 3.—RELATION BETWEEN STABILITY AND THE PENETRATION OF THE ASPHALT AT TWO TEST TEMPERATURES.

TABLE 1.—*Hubbard-Field stability of mixtures containing various grades of Mexican asphalt*

Identification	Softening point, ring and ball	Penetration at 77° F.	Estimated penetration at— 140° F.	Estimated penetration at— 122° F.	Hubbard-Field stability at— 140° F.	Hubbard-Field stability at— 122° F.
	°F.				*Pounds*	*Pounds*
M-20	147	23	525	215	2,800 2,900 3,600	4,500 4,550 4,400
M-30	139	38	880	360	2,500 2,450 2,450	3,550 3,650 3,400
M-40	138	45	1,050	430	2,200 2,200 2,200	3,450 3,350 3,300
M-50	131	56	1,260	515	2,050 1,950 1,950	2,900 3,100 3,100
M-60	128	64	1,470	600	1,600 1,900 1,800	3,050 2,550 2,550
M-70	126	74	1,680	----------	1,850 1,850 1,850	
M-85	121	95	2,100	860	2,200 1,800 1,850	2,450 2,650 2,600
M-100	121	100	2,300	----------	1,600 1,580 1,650	
M-120	114	144	3,150	1,290	1,500 1,550 1,530	1,800 1,700 1,900
M-180	109	182	4,200	1,720	1,250 1,300 1,250	1,800 1,850 1,850

SUSCEPTIBILITY TO TEMPERATURE AND BONDING STRENGTH OF ASPHALT DETERMINE STABILITY OF MIXTURE

Figure 7 shows the relation between the stability at 140° F. and the penetration of the asphalt at 77° F. for all mixtures including those made with the Mexican asphalts. In every case the softer grades of asphalt gave lower stability values than the harder grades of asphalt from the same producer, but the decrease in stability was not the same for all the samples. Stability values from figure 7 show that the stability of specimens made with 100-penetration asphalts varied from 69 to 91 percent of the stability of specimens made with 50-penetration asphalt from the same producer.

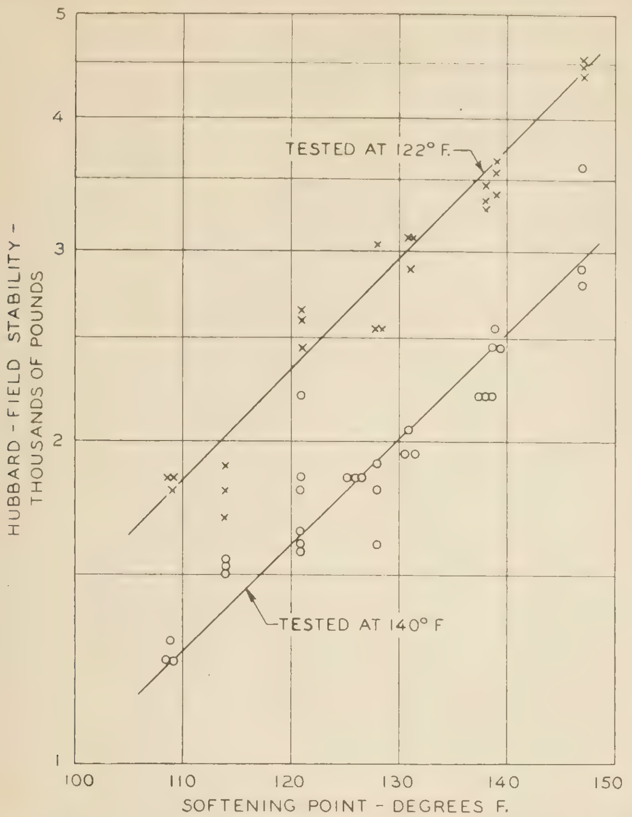

FIGURE 4.—RELATION BETWEEN STABILITY AT 122° F., AND 140° F., AND THE SOFTENING POINT OF THE CONTAINED MEXICAN ASPHALT.

TABLE 2.—*Characteristics of the asphalts used in the second series of tests*

Identification	Penetration at 77° F.	Softening point	Slope of penetration curve	Penetration at softening point
		°F.		
A-50	61	118	0.031	1,060
A-85	96	111	.031	1,120
B-50	58	137	.017	630
B-85	90	121	.019	620
C-50	57	130	.022	750
C-85	97	115	.023	720
D-50	60	120	.029	1,080
D-85	91	112	.028	840
E-50	50	123	.024	630
E-85	87	113	.026	760

They also show that the stability of specimens made with 50-penetration asphalt D was only 56 percent of the stability of specimens made with 50-penetration asphalt M. Thus there was a greater percentage difference in the stability of specimens made with 50-penetration asphalt from different producers than in the stability of specimens made with 50- and 100-penetration asphalts from the same producers.

In figure 8 the logarithm of the stability of the second series of mixtures is plotted against the logarithm of the penetration of the 50- and 85-penetration asphalts at the temperature of the stability test. In this figure, as in figure 3 for the Mexican asphalts, the points for asphalts from the same producer fall approximately upon the same straight line.

Table 4 gives the stabilities of mixtures containing each asphalt at the temperature at which the asphalt had an estimated penetration of 1,000. Values for this table are taken from figures 3 and 8. Since all the asphalts had the same consistency, the differences in stability values must have been caused by some in-

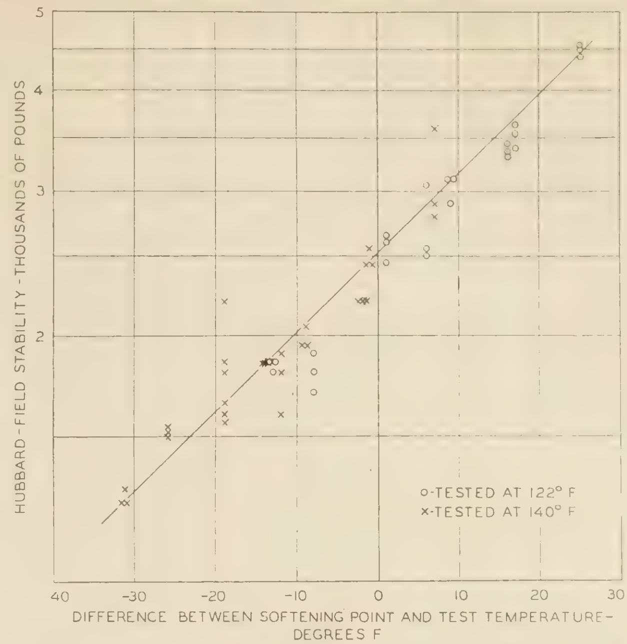

FIGURE 5.—RELATION BETWEEN THE HUBBARD-FIELD STABILITY AND THE TEMPERATURE DIFFERENCE BETWEEN THE SOFTENING POINT OF THE CONTAINED BITUMEN AND THE TEST TEMPERATURE.

TABLE 3.—*Hubbard-Field stability of mixtures containing two grades of asphalt from various producers*

Identification	Penetration at 77° F.	Estimated penetration at—			Hubbard-Field stability at—		
		140° F.	122° F.	104° F.	140° F.	122° F.	104° F.
					Pounds	*Pounds*	*Pounds*
A-50	61	5,000	1,400	390	1,050	1,950	3,150
					1,250	1,770	3,200
					1,250	2,020	3,300
A-85	96	9,000	2,450	660	1,100	1,750	2,700
					1,050	1,580	2,650
					1,100	1,500	2,800
B-50	58	720	350	170	1,700	2,850	4,600
					1,700	2,850	5,000
					1,700	2,600	4,300
B-85	90	1,400	650	295	1,400	2,500	3,300
					1,400	1,950	3,100
					1,300	2,050	3,500
C-50	57	1,450	590	230	1,600	2,500	4,000
					1,600	2,520	3,750
					1,550	2,250	3,900
C-85	97	2,650	1,050	400	1,100	1,900	3,250
					1,250	1,860	3,050
					1,250	1,900	3,200
D-50	60	4,200	1,300	380	1,250	2,020	3,500
					1,150	2,150	3,250
					1,200	1,750	3,050
D-85	91	5,000	1,600	500	1,050	1,750	2,650
					1,200	1,650	2,650
					1,150	1,550	2,750
E-50	50	1,600	600	225	1,450	2,470	4,550
					1,900	2,000	4,000
					1,300	2,350	4,500
E-85	87	4,000	1,350	440	1,100	1,840	3,200
					1,100	2,100	3,150
					1,100	1,800	3,150

TABLE 4.—*Stabilities of asphaltic mixtures tested at temperatures at which the asphalt would have a penetration of 1,000*

Identification	Stability	Identification	Stability
	Pounds		*Pounds*
M	2,300	C	1,900
A	2,250	D	2,100
B	1,500	E	2,000

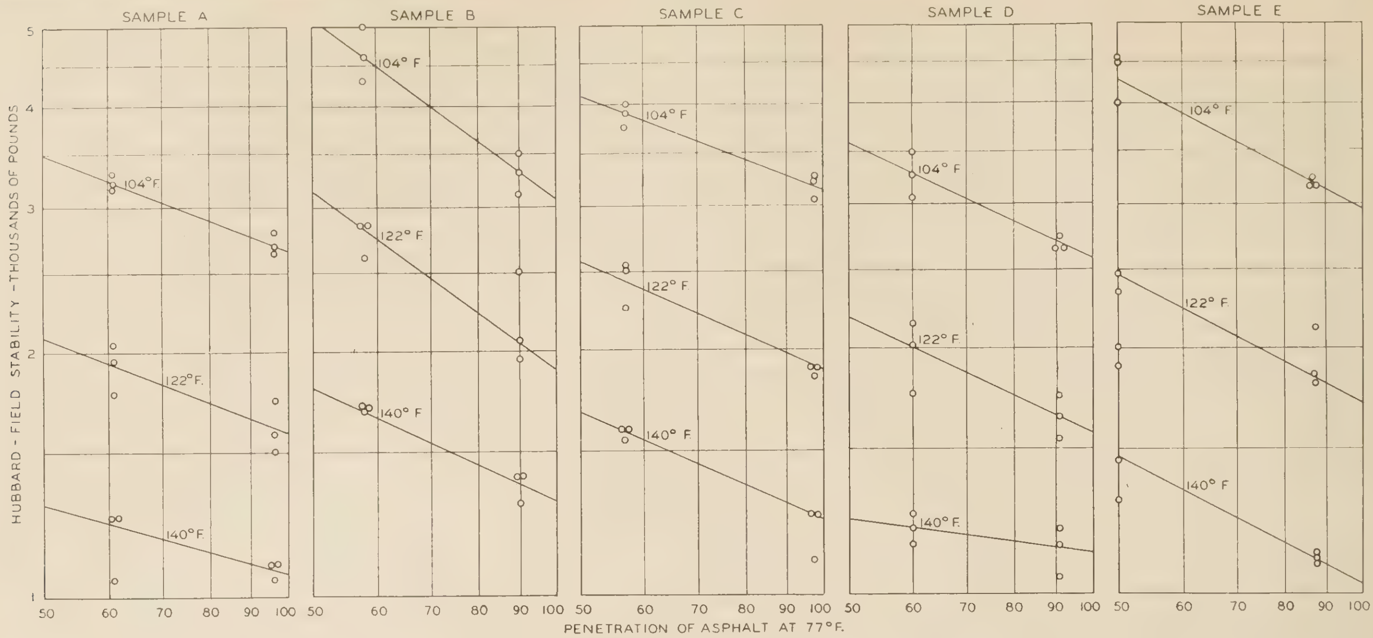

FIGURE 6.—RELATION BETWEEN STABILITY AT VARIOUS TEMPERATURES AND THE PENETRATION AT 77° F. OF THE VARIOUS TYPES OF CONTAINED ASPHALT.

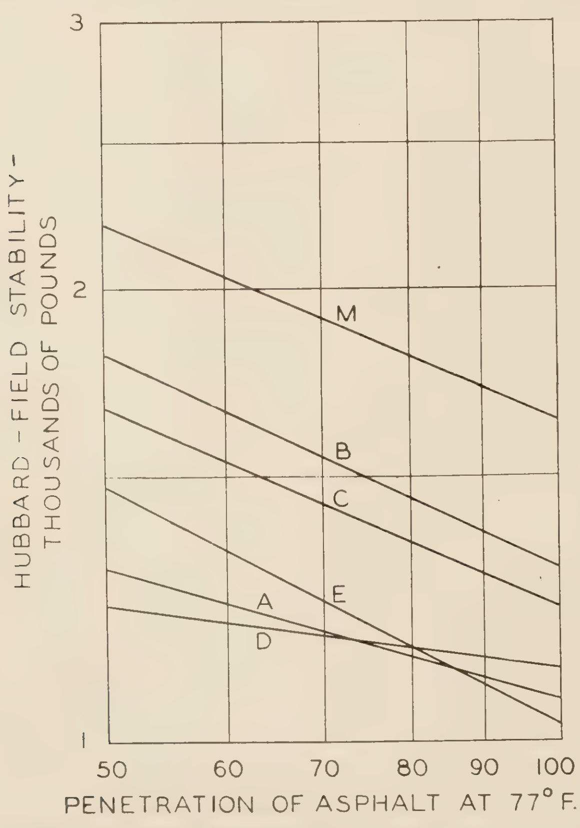

FIGURE 7.—RELATION BETWEEN STABILITY AT 140° F. AND THE PENETRATION AT 77° F. OF THE CONTAINED ASPHALT.

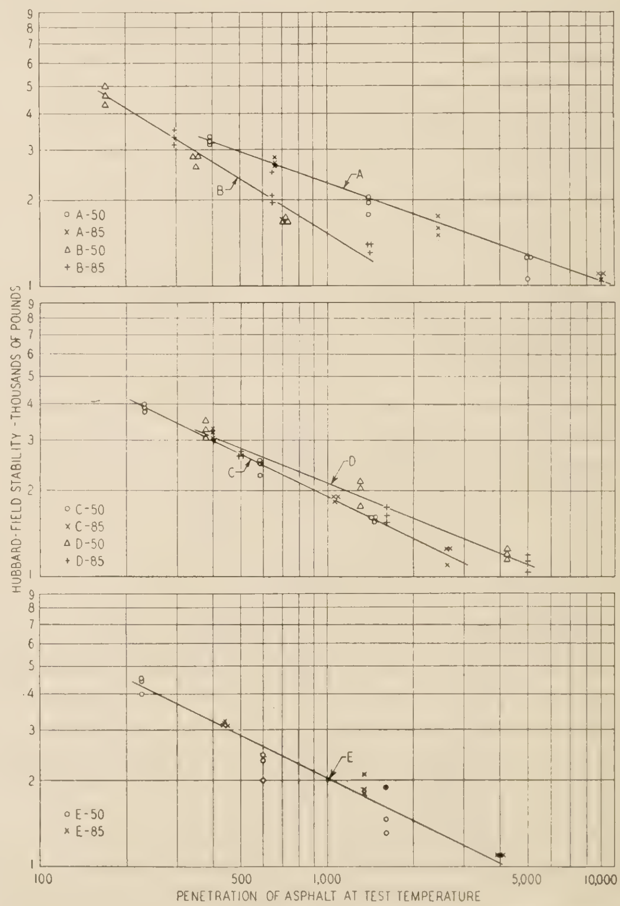

FIGURE 8.—RELATION BETWEEN STABILITY AND THE PENETRATION AT TEST TEMPERATURE OF THE VARIOUS CONTAINED ASPHALTS.

herent quality of the asphalt which, in this report, is called bonding strength. Thus asphalt B may be assumed to have the least bonding strength, while asphalts M and A had the greatest bonding strength.

There are then two characteristics of an asphalt which determine the stability at any temperature of mixture containing it; its susceptibility to temperature, and its bonding strength. For example, table 4 shows asphalts A and M to have about the same bonding

(Continued on page 82)

THE DETERMINATION OF SODIUM AND POTASSIUM IN CEMENTS

BY THE DIVISION OF TESTS, PUBLIC ROADS ADMINISTRATION

Reported by L. G. CARMICK, Associate Chemist

IN ENDEAVORS to find reasons for the often erratic behavior of portland cements, interest has turned recently toward minor constituents that are commonly ignored in analysis. There is particular interest in knowing to what extent sodium and potassium compounds are present. These elements and their compounds, which for convenience may be referred to simply as alkalies, seem to be present in all cements to the extent of at least 0.3 or 0.4 percent, and cements made in some parts of the United States contain appreciably over 1 percent. What effect alkalies have on the behavior of cements is still uncertain, but there is reason for believing that they do exert an influence. It therefore seems likely that determination of alkalies will be a more frequent task in the future than it has been heretofore.

The method that has always been relied on for the determination of alkalies is that proposed many years ago by J. Lawrence Smith. This method was intended primarily for use in the analysis of igneous rocks, which are very difficult to bring into solution. While it is capable of yielding excellent results in the hands of a careful analyst, the method has several disadvantages that may easily lead to error. In the first place, it is necessary to use large amounts of reagents, particularly calcium carbonate which is often impure. This makes it necessary to run blanks and make corrections. Secondly, in the long heating or "fusion" there is some uncertainty that all the alkali has been rendered soluble, and if the temperature has been too high some of the alkali may have been volatilized. Thirdly, there are large amounts of insoluble matter to wash; and finally, the method is tedious and requires constant attention.

NEW METHOD GIVES ACCURATE RESULTS

For these reasons a better method was sought. The following procedure was found to be quite satisfactory and largely free from the objections just noted. It has now been tried out by several analysts and found to give very accurate results.

While any reasonable quantity of cement may be used, it is convenient to take 15.625 grams. Put this in a beaker or evaporating dish and add enough water to make a thin grout, then add enough hydrochloric acid to decompose the cement completely. Evaporate to dryness on the hot plate but do not bake. Add about 300 milliliters of water and digest on the hot plate for half an hour, then heat to boiling. Most of the silica and R_2O_3 group will now be precipitated and in suspension. Add 2 or 3 drops of phenolphthalein indicator and then, a little at a time, some pure quicklime until the solution is strongly alkaline as shown by the pink color. Quicklime is an excellent precipitant for magnesia as well as for silica and the R_2O_3 group, and also the precipitate caused by lime is less voluminous than that caused by ammonia. The freshly ignited lime obtained in the ordinary analysis of cement does very well and about 1 gram is usually enough.

Boil gently for a few minutes, allow to cool somewhat, and transfer to a 500-milliliter volumetric flask. Add water to bring the volume to 500 milliliters, mix well, and allow the precipitate to settle. Decant through a filter just 400 milliliters of the supernatant liquid. This 400 milliliters should contain only lime and the alkalies from 12.5 grams of cement. After obtaining the 400 milliliters of filtrate, the residue and precipitate in the flask are discarded without further treatment.

To the filtrate add a solution of ammonium carbonate and ammonium hydroxide in sufficient amount to precipitate all the lime, avoiding unnecessary excess. Boil gently, allow to cool somewhat, transfer to a 500 milliliter volumetric flask, add water to bring the volume to 500 milliliter, mix well, and allow the lime to settle. Decant through a filter just 400 milliliter of the supernatant liquid, discard the residue, and precipitate in the flask. The filtrate thus obtained should contain only the alkalies from just 10 grams of cement together with ammonium salts and perhaps a very little lime. Add to this filtrate about 1 milliliter of concentrated sulphuric acid, evaporate in a platinum dish, and volatilize the ammonium salts. Dissolve the residue in 30 or 40 milliliters of water and add a little quicklime in order to throw down any magnesia that may possibly have escaped the first precipitation. Filter into a small beaker, add ammonia water and ammonium oxalate, warm to precipitate the last of the lime, and filter into a platinum dish. Add a drop or two of sulphuric acid, evaporate to dryness, and volatilize the ammonium salts. Heat to dull redness for a moment, cool, and weigh the sodium and potassium sulphates.

Recently the following modification has been tried and found to add to the convenience of the method in that it does away with the necessity of drying and volatilizing large amounts of ammonium salts.

Instead of precipitating the lime with ammonium carbonate, place the 400 milliliters of filtrate from the silica and R_2O_3 group in a 500-milliliter volumetric flask and add slightly more oxalic acid in hot concentrated solution than can combine with the lime that is present. The amount of oxalic acid is determined by multiplying the number of grams of CaO by 2.25 and adding 1 gram more. Add enough water to make up 500 milliliters of solution, mix well, and allow the precipitate to settle. Although hydrochloric acid is present, nearly all of the lime will be precipitated. Decant through a filter 400 milliliters of the liquid, discard the residue, and precipitate in the flask. Evaporate the filtrate in platinum on the steam bath to practical dryness. Add at least 50 milliliters of water, digest well on the steam bath, make ammoniacal, and filter into a small beaker. Test the filtrate with ammonium oxalate to insure the absence of lime. Add a few drops of concentrated sulphuric acid, evaporate to dryness on the steam bath in platinum, and volatilize the ammonium salts, which in this case will be only a small amount. The residue in the dish should be the pure alkali sulphates; this may be verified by testing for the presence of traces of magnesium and calcium compounds.

From this point, the sodium and potassium may be separated in the usual manner by platinic chloride if it is desired to do so. If it be assumed that sodium and potassium are present in equal quantities, the amount of Na_2O plus K_2O is found by multiplying the weight of the mixed sulphates by 0.4884.

The amount of cement used for analysis is of course optional with the analyst. If 7.8125 grams are taken instead of double that amount as suggested herein the result will be the alkalies from 5 grams instead of 10. In such case it is quite feasible to use 250-milliliter volumetric flasks instead of the 500 size, and there is less liquid to evaporate.

The large precipitates that are discarded may seem at first thought to be a source of error, but it can be shown that their actual volume is such that the error caused thereby is negligible. It will be observed that a minimum of reagents is used in this method and those that are used are readily obtainable in very pure form. It will of course be understood that whenever water is referred to, distilled water of the highest purity is meant.

(Continued from page 68)

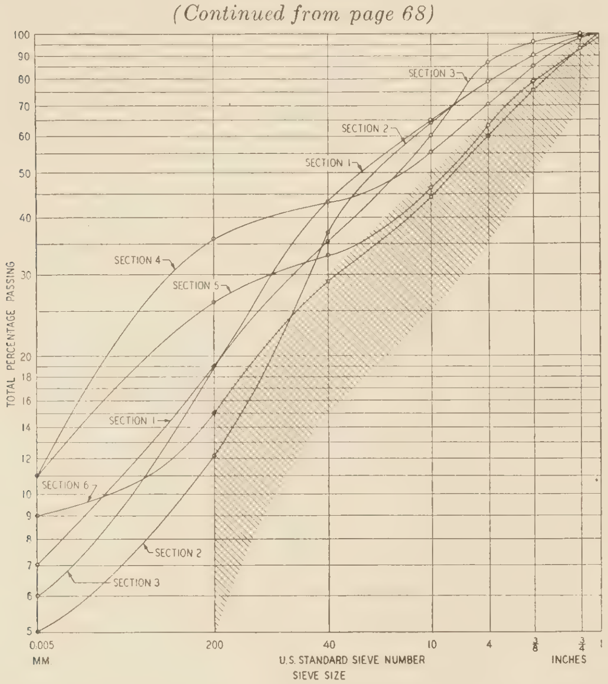

FIGURE 5.—GRADINGS OF MATERIALS. SHADED AREA INDICATES ZONE WITHIN WHICH ARE INCLUDED THE SPECIFICATION REQUIREMENTS OF THE A. A. S. H. O. FOR COARSE-GRADED TYPE AGGREGATE BASE-COURSE MATERIALS HAVING 1-INCH MAXIMUM SIZE.

however, contained hydrated lime, which has the property of increasing the liquid limits and reducing the plasticity indexes when added to many soils.

Previous investigations have shown that, with the ground-water elevation ½ inch above the top of the sub-base, concentrated traffic provides a condition that is sufficiently severe to enable identification of the definitely unsatisfactory materials. Using this as a criterion, the mixtures tested would be rated as shown in table 6.

TABLE 6.—*Rating of sections after testing under concentrated traffic, with water elevation ½ inch above the top of the sub-base*

Section No.	Composition	Admixture of hydrated lime	Service rating
		Percent	
1	Chert A-sand	0	Unsatisfactory.
2	Chert A-sand	5	Good.
3	Chert A-slag	0	Borderline.
4	Chert B	0	Complete failure.
5	Chert B	5	Unsatisfactory.
6	Chert C	5	Good.

The addition of hydrated lime to the sand-chert A mixture and to chert B resulted in improved performance of the materials when used as base courses. The results obtained in the track with a combination of basic granulated slag and chert A were superior to those with a combination of sand and chert A.

Section 1 became unstable with the water ½ inch above the top of the sub-base and had failed completely at 124,400 wheel-trips. Section 2, which differed from section 1 only by the addition of 5 percent of hydrated lime, gave excellent service as a base course throughout all phases of the testing. Section 3 withstood the 40,000 wheel-trips of concentrated traffic with water at the ½-inch level without excessive movement in the base. However, with continued traffic and increased elevation of the ground water, the vertical displacements continued to increase at a fairly uniform rate (see fig. 1) until at the end of the test the section was in an unsatisfactory condition, as shown in figure 4.

The grading and plasticity index of the mixture used in section 1 are indicated to be responsible for the failure of this section when tested as a base course. Section 2 was composed of the same materials with an admixture of hydrated lime. Its grading was only slightly better than that of section 1 and could not be responsible for the marked difference in behavior, but it was nonplastic with a plasticity index of 0. Similarly, the grading of the section 3 material was not widely different from that of section 1 but it had a plasticity index intermediate between those of sections 1 and 2. Its behavior under traffic was much superior to that of section 1, although not as good as that of section 2.

The tests (see table 5) made at the time of failure or the end of testing show that section 2 had 64.7 percent of solids by volume, or considerably less than either of the other two sections in which chert A was used. Therefore, the differences in behavior of the sections cannot be ascribed to differences in compaction, since previous investigations have led to the conclusion that, for a given material, increase in density would produce increase in stability.

Section 4, chert B, failed immediately when subjected to concentrated traffic with water in the sub-base. Section 5 (chert B with an admixture of hydrated lime) became slightly unstable under these testing conditions but did not fail completely until water was raised to the 4½-inch level and wheel loads were increased from 800 to 1,000 pounds. The gradings of the section 4 and section 5 materials were similar and the plasticity indexes were 2 and 0, respectively. Again the track density in the lime-treated section was less than that of the untreated section.

Section 6 consisted of a mixture of chert gravels with a 5 percent hydrated lime admixture. The grading of this mixture conformed with the A. A. S. H. O. specifications for base-course materials, yet each of the cherts came from a location on a highway where base failure had occurred. However, with the lime admixture this composite material gave good service in the track, except that near the end of the test a small, soft spot developed (see fig. 4). This resulted in the abrupt change in slope of the displacement curves shown in figure 1. It should be emphasized that this softening was confined to one spot and did not represent the entire section. The condition developed only under the most extreme testing conditions and is thought to have been caused by some construction feature, since samples from the rutted and intact portions of the section had almost identical compositions and densities.

CONCLUSIONS

The following conclusions appear to be justified:

1. Although only three chert gravels were investigated, there are strong indications that the behavior as base courses of this class of local materials can be greatly improved by the addition of a basic material such as hydrated lime or granulated slag. Other possible admixtures include limestone or slag screenings, lime wastes, and similar materials of a basic character which may be economically available.

2. It is indicated that the beneficial action of the basic admixture will be greater if the material is in a finely divided state, except where it is intended to perform the dual purpose of improving the grading and altering the physical characteristics of the material.

3. The addition of 5 percent of hydrated lime to a composite chert (sec. 6), conforming to the grading requirements of the A. A. S. H. O. specifications for base-course materials produced a mixture which gave good service when tested in the circular track even though all of the cherts which were combined had come from locations where base-course failures had been observed.

4. The addition of 5 percent of hydrated lime to the chert B which did not meet these grading requirements resulted in a marked improvement in the behavior of this material under test traffic. (Compare secs. 4 and 5.)

5. Lime also greatly improved the performance of the chert A to which sand had been added to reduce the plasticity index to approximately the upper limit of the A. A. S. H. O. specification. (Compare sections 1 and 2.)

6. Basic granulated slag added to chert A in an amount sufficient to lower the plasticity index to 5 resulted in a mixture that was more stable when tested in the circular track than the mixture of sand and chert A without hydrated lime. (Compare sections 1 and 3.)

7. Density as such is not a true measure of the stability of granular mixtures. For any one given material an increase in density is accompanied by an increase in stability, but for materials having different compositions, the one having the greatest density may or may not be the most stable. Thus in the present investigation, in all cases where a direct comparison is possible, the mixtures containing lime had lower densities than the corresponding sections without lime; yet their behavior in the track showed the sections with lime to be the more stable.

8. No specifications for chemically treated chert-gravel base-course materials can be prepared from the information so far developed. It is suggested, however, that this class of material be used only if the grading conforms to or closely approaches the A. A. S. H. O. specification for base-course materials, and if the admixture reduces the plasticity index of the fraction passing the No. 40 sieve to 3 or less. It is believed that if these conditions are met the liquid limit of acceptable mixtures containing basic ingredients may be as high as 35.

(Continued from page 74)

5. That decreasing the temperature of a mixture increases its strength and stiffness. It is probable, however, that there is some limiting temperature below which the strength and stiffness of a mixture would not be increased.

6. That increasing the amount of asphalt in a mixture up to the amount required to fill the voids increases its strength but has little effect upon the stiffness of the mixture. Increasing the amount of dust in a mixture up to the amount required to fill the voids increases both the strength and stiffness of the mixture.

As a result of these tests the following suggestions are made regarding a suitable test procedure:

1. A test temperature of 39° F. appears to have definite advantages. This temperature may be obtained and held constant with a bath containing very little ice. Temperatures below this are hard to maintain and require a large amount of ice which interferes with the correct placing of the specimen. At higher temperatures the strength and stiffness decrease and it would be difficult to distinguish between mixtures.

2. Preferably, the span length should be 10 inches for all depths of beam up to a maximum of 2 inches, since table 2 shows that with this span length there is the least variation in modulus of elasticity with changes in depth of beam. When it is necessary to vary both the span length and depth of beam, the following dimensions are suggested as likely to result in the least variation in the modulus of elasticity:

Depth:	*Minimum span (inches)*
Less than 1.3 inches	6
1.3 to 1.7 inches	8
Over 1.7 inches	10

3. The rate at which unit fiber stress is developed should be constant and this may be accomplished by applying the load at the rate determined by the formula

$$R=\frac{Cbd^2}{l}$$

in which

R=rate of loading in pounds per minute;
C=constant; and

l, b, and d are the same as in the previous formulas in this report. Two hundred and twenty is suggested as a suitable value for C. The rate of loading determined with C=220 will allow a wide range in the size of the specimen that can be tested on the machine that has been described and the load will be applied at a slow enough rate so that deflection measurements every 10 seconds will give a good load-deformation curve.

(*Continued from p. 78*)

strength, but asphalt A was much more susceptible to temperature and specimens made with both grades of asphalt A had lower stability at 140° F. than specimens made with the corresponding grades of asphalt M.

Asphalts M and C had about the same susceptibility to temperature. Table 4 shows asphalt C to have had less bonding strength than asphalt M, and specimens made with both grades of asphalt C had less stability at 140° F. than specimens made with the corresponding grades of asphalt M (tables 1 and 3).

A stability test using a standard aggregate made at a temperature at which the contained asphalt had a definite penetration might prove to be of value in testing the bonding strength of asphalts for use in road construction.

Because the stability of mixtures containing asphalts of the same type, that is, having the same susceptibility to temperature and the same bonding strength, depends only upon the consistency of the asphalt at the temperature of the stability test, it is not necessary to make tests with all grades of asphalt in order to determine the effect of using different grades of asphalt upon stability. By determining the stability at several temperatures of a mixture containing one grade of asphalt whose penetration has been determined at several temperatures, temperature-penetration and penetration-stability curves can be drawn. For similar types of asphalt the penetration at any temperature of any grade of asphalt can be approximated from the temperature-penetration curve for one grade of asphalt. The stability of the mixture can then be estimated from the penetration-stability curve.

SUMMARY

In these tests on mixtures of constant composition except for the type and consistency of the asphalt it was found that:

1. There were greater differences in the stability of mixtures made with the same grade of asphalts from different producers than there were in the stability of mixtures made with the 50- and 100-penetration grades of asphalt from the same producer. There was as much as 45 percent variation in the stability at 140° F. of the mixtures containing the various 50-penetration asphalts. For materials from the same producer, doubling the penetration of the asphalt reduced the stability of the mixture by from 10 to 30 percent.

2. There is some characteristic of an asphalt which caused mixtures made with various types of asphalt to vary in stability even when the asphalts were of the same consistency when the mixtures were tested for stability. This quality, for lack of a better term, is here called bonding strength.

3. For asphalts of the same type, that is, having approximately the same susceptibility to temperature and the same consistency at their softening point, the stability of the mixtures depended upon the consistency of the asphalt at the temperature of the stability test.

MOTOR-FUEL CONSUMPTION-1939

COMPILED FOR CALENDAR YEAR FROM REPORTS OF STATE AUTHORITIES 1/

TABLE G-2, 1939
ISSUED MAY 1940

STATE	TAX RATE PER GALLON ON DECEMBER 31	GROSS AMOUNT REPORTED 2/	AMOUNT EXEMPTED FROM PAYMENT OF TAX 3/	GROSS AMOUNT ASSESSED FOR TAXATION	AMOUNT SUBJECT TO REFUND OF ENTIRE TAX	NET AMOUNT TAXED: TOTAL	NET AMOUNT TAXED: AT PREVAILING RATE	NET AMOUNT TAXED: AT OTHER RATES: RATE PER GALLON	NET AMOUNT TAXED: AT OTHER RATES: AMOUNT	AMOUNT TAXED AT PREVAILING RATE DURING 1938	INCREASE OR DECREASE DURING 1939: AMOUNT	INCREASE OR DECREASE DURING 1939: PERCENT	STATE
	Cents	1,000 gallons	1,000 gallons	1,000 gallons	1,000 gallons	1,000 gallons	1,000 gallons	Cents	1,000 gallons	1,000 gallons	1,000 gallons		
ALABAMA	6	241,375	-	241,375	-	241,375	241,375	-	-	226,838	14,537	6.4	ALABAMA
ARIZONA	5	107,475	5,167	102,308	12,369	89,939	89,939	-	-	84,534	5,405	6.4	ARIZONA
ARKANSAS	6.5	181,922	7,312	174,610	-	174,610	155,709	(4/)	18,901	143,479	12,230	8.5	ARKANSAS
CALIFORNIA	3	1,852,859	27,148	1,825,711	151,931	1,673,780	1,673,780	-	-	1,571,928	101,852	6.5	CALIFORNIA
COLORADO	4	237,669	8,508	229,161	33,014	196,147	196,147	-	-	187,944	8,203	4.4	COLORADO
CONNECTICUT	3	351,315	8,447	342,868	7,722	335,146	335,146	-	-	312,710	22,436	7.2	CONNECTICUT
DELAWARE	4	59,316	1,269	58,047	3,637	54,410	54,410	-	-	52,490	1,920	3.7	DELAWARE
FLORIDA	7	363,710	13,621	350,089	-	350,089	350,089	-	-	326,838	23,251	7.1	FLORIDA
GEORGIA	6	362,403	9,541	352,862	-	352,862	352,862	-	-	328,921	23,941	7.3	GEORGIA
IDAHO	5/ 5.1	100,802	3,635	97,167	-	97,167	6/ 88,444	(7/)	8,723	81,888	6,556	8.0	IDAHO
ILLINOIS	3	1,448,697	-	1,448,697	112,464	1,336,233	1,336,233	-	-	1,256,016	80,217	6.4	ILLINOIS
INDIANA	4	651,249	2,016	649,233	50,499	598,734	598,734	-	-	562,879	35,855	6.4	INDIANA
IOWA	3	550,333	-	550,333	81,231	469,102	469,102	-	-	445,906	23,196	5.2	IOWA
KANSAS	3	467,296	132,719	334,577	-	334,577	334,577	-	-	337,527	-2,950	-0.9	KANSAS
KENTUCKY	5	275,107	-	275,107	-	275,107	275,107	-	-	256,516	18,591	7.2	KENTUCKY
LOUISIANA	7	261,304	6,228	255,076	5	255,071	247,419	2	8/ 7,652	234,941	12,478	5.3	LOUISIANA
MAINE	4	150,136	831	149,305	-	149,305	141,850	1	9/ 7,455	137,406	4,444	3.2	MAINE
MARYLAND	4	291,666	4,106	287,560	19,633	267,927	265,548	3	10/ 2,379	246,433	19,115	7.8	MARYLAND
MASSACHUSETTS	3	721,112	2,829	718,283	34,550	683,733	683,733	-	-	662,254	21,479	3.2	MASSACHUSETTS
MICHIGAN	3	1,146,327	99,359	1,046,968	52,381	994,587	994,058	1.5	11/ 529	928,920	65,138	7.0	MICHIGAN
MINNESOTA	4	559,186	25,686	533,500	63,922	469,578	469,578	-	-	447,444	22,134	4.9	MINNESOTA
MISSISSIPPI	6	205,963	9,032	196,931	-	196,931	188,426	1	12/ 8,505	171,044	17,382	10.2	MISSISSIPPI
MISSOURI	2	653,611	-	653,611	32,820	620,791	620,791	-	-	581,086	39,705	6.8	MISSOURI
MONTANA	5	128,980	8,497	120,483	21,564	98,919	98,919	-	-	89,450	9,469	10.6	MONTANA
NEBRASKA	5	242,721	10,515	232,206	6	232,200	232,119	1	13/ 81	223,309	8,810	3.9	NEBRASKA
NEVADA	4	39,258	2,494	36,764	2,370	34,394	33,618	5	14/ 776	29,958	3,660	12.2	NEVADA
NEW HAMPSHIRE	4	91,831	-	91,831	3,383	88,448	88,448	-	-	82,714	5,734	6.9	NEW HAMPSHIRE
NEW JERSEY	3	849,139	3,055	846,084	72,738	773,346	773,346	-	-	742,435	30,911	4.2	NEW JERSEY
NEW MEXICO	5	102,064	6,349	95,715	9,270	86,445	86,374	7.5	15/ 71	81,521	4,853	6.0	NEW MEXICO
NEW YORK	4	1,900,715	69,381	1,831,334	63,046	1,768,288	1,768,288	-	-	1,684,672	83,616	5.0	NEW YORK
NORTH CAROLINA	6	430,291	7,597	422,694	-	422,694	410,340	1	12/ 12,354	385,834	24,506	6.4	NORTH CAROLINA
NORTH DAKOTA	16/ 4	130,238	27,652	102,586	19,892	82,694	17/ 82,694	-	-	85,775	-3,081	-3.6	NORTH DAKOTA
OHIO 18/	4	1,371,266	68,887	1,302,379	11,494	1,290,885	1,231,223	1	9/ 59,662	1,157,015	74,208	6.4	OHIO 18/
OKLAHOMA	4	421,496	39,967	381,529	15,794	365,735	365,735	-	-	350,190	15,545	4.4	OKLAHOMA
OREGON	5	245,746	5,298	240,448	26,912	213,536	212,609	1	19/ 927	197,797	14,812	7.5	OREGON
PENNSYLVANIA	4	1,482,428	6,351	1,476,077	-	1,476,077	1,476,077	-	-	1,397,068	79,009	5.7	PENNSYLVANIA
RHODE ISLAND	3	129,878	1,198	128,680	1,985	126,695	126,695	-	-	116,874	9,821	8.4	RHODE ISLAND
SOUTH CAROLINA	6	210,980	-	210,980	4,027	206,953	206,953	-	-	188,783	18,170	9.6	SOUTH CAROLINA
SOUTH DAKOTA	4	136,628	4,934	131,694	29,722	101,972	101,972	-	-	99,668	2,304	2.3	SOUTH DAKOTA
TENNESSEE	7	288,738	17,025	271,713	1,491	270,222	270,222	-	-	264,163	6,059	2.3	TENNESSEE
TEXAS	4	1,337,584	16,626	1,320,958	180,516	1,140,442	1,140,442	-	-	1,075,851	64,591	6.0	TEXAS
UTAH	4	99,746	5,397	94,349	-	94,349	94,349	-	-	87,850	6,499	7.4	UTAH
VERMONT	4	68,009	872	67,137	-	67,137	67,137	-	-	63,300	3,837	6.1	VERMONT
VIRGINIA	5	382,173	-	382,173	23,532	358,641	358,541	3	20/ 100	334,327	24,214	7.2	VIRGINIA
WASHINGTON	5	354,142	8,090	346,052	25,111	320,941	320,941	-	-	309,697	11,244	3.6	WASHINGTON
WEST VIRGINIA	5	215,100	-	215,100	3,026	212,074	212,074	-	-	188,915	23,159	12.3	WEST VIRGINIA
WISCONSIN	4	566,693	17,101	549,592	41,816	507,776	507,776	-	-	484,812	22,964	4.7	WISCONSIN
WYOMING	4	68,014	2,341	65,673	-	65,673	65,673	-	-	63,376	2,297	3.6	WYOMING
DISTRICT OF COLUMBIA	2	150,365	6,523	143,842	1,066	142,776	142,776	-	-	133,325	9,451	7.1	DISTRICT OF COLUMBIA
TOTAL	21/ 3.96	22,685,056	703,604	21,981,452	1,214,939	20,766,513	20,638,398	-	128,115	19,504,621	1,133,777	5.8	TOTAL

1/ AN ANALYSIS OF MOTOR-FUEL USAGE WILL BE GIVEN IN TABLE G-21, TO BE PUBLISHED LATER.

2/ EXPORT SALES AND OTHER AMOUNTS NOT REPRESENTING CONSUMPTION IN STATE HAVE BEEN ELIMINATED AS FAR AS POSSIBLE. IN CASES WHERE STATES FAILED TO REPORT AMOUNTS EXEMPTED FROM TAXATION, THE GROSS AMOUNT TAXED IS SHOWN IN THIS COLUMN.

3/ INCLUDES ALLOWANCES FOR EVAPORATION AND OTHER LOSSES, FEDERAL USE, OTHER PUBLIC USE, AND NONHIGHWAY USE, WHERE INITIAL EXEMPTIONS RATHER THAN REFUNDS ARE MADE.

4/ WITHIN 300 FEET OF BORDER, TAX IS REDUCED TO THAT OF ADJACENT STATE. GALLONS TAXED AT 2 CENTS, 4,807,000; AT 4 CENTS, 14,094,000.

5/ RATE CHANGED FROM 5 CENTS TO 5.1 CENTS MARCH 11.

6/ GALLONS TAXED AT 5 CENTS, 3,003,000; AT 5.1 CENTS, 85,441,000.

7/ AVIATION FUEL TAXED AT 2.5 CENTS, 180,000 GALLONS; MOTOR FUEL TAXED AT 0.1 CENT (NONHIGHWAY USE REFUNDED 5 CENTS), 8,543,000 GALLONS.

8/ REPRESENTS EVAPORATION OR LOSS ALLOWANCE UNDER 5-CENT TAX NOT ALLOWED UNDER ADDITIONAL 2-CENT TAX, WHICH IS ADMINISTERED UNDER A SEPARATE LAW.

9/ THREE CENTS PER GALLON REFUNDED ON NONHIGHWAY USES.

10/ ONE CENT PER GALLON REFUNDED ON MOTOR FUEL USED IN VEHICLES LICENSED TO OPERATE EXCLUSIVELY IN CITIES.

11/ ONE AND ONE-HALF CENTS PER GALLON REFUNDED ON MOTOR FUEL USED IN INTERSTATE AVIATION.

12/ FIVE CENTS PER GALLON REFUNDED ON NONHIGHWAY USES.

13/ AVIATION FUEL USED IN FLYING INSTRUCTION.

14/ DIESEL FUEL TAXED AT 5 CENTS PER GALLON EFFECTIVE JULY 1.

15/ DIESEL FUEL TAXED AT 7.5 CENTS PRIOR TO JULY 1. TAXED AT REGULAR RATE THEREAFTER.

16/ RATE CHANGED FROM 3 CENTS TO 4 CENTS JULY 1.

17/ GALLONS TAXED AT 3 CENTS, 35,693,000; AT 4 CENTS, 47,001,000.

18/ AMOUNTS GIVEN DO NOT INCLUDE 67,765,000 GALLONS OF LIQUID FUEL (KEROSENE, FUEL OIL, ETC.) TAXED AT 1 CENT PER GALLON BUT NOT SUBJECT TO THE 3-CENT TAX ON MOTOR-VEHICLE FUEL.

19/ FOUR CENTS PER GALLON REFUNDED ON MOTOR FUEL USED IN AVIATION.

20/ TWO CENTS PER GALLON REFUNDED ON MOTOR FUEL USED IN INTRASTATE AVIATION.

21/ WEIGHTED AVERAGE RATE.

STATE MOTOR-FUEL TAX RECEIPTS - 1939

COMPILED FOR CALENDAR YEAR FROM REPORTS OF STATE AUTHORITIES

TABLE G-1, 1939
ISSUED MAY 1940

STATE	TAX RATE PER GALLON ON DECEMBER 31	RECEIPTS FROM TAXATION OF MOTOR FUEL					OTHER RECEIPTS IN CONNECTION WITH MOTOR-FUEL TAX 2/					NET TOTAL RECEIPTS	LESS TAX ON AVIATION GASOLINE	ADJUSTED NET TOTAL RECEIPTS	STATE
		GROSS TAX COLLECTIONS	DEDUCTIONS BY DISTRIBUTORS FOR EXPENSES 1/	GROSS RECEIPTS BY STATE	REFUNDS PAID	NET RECEIPTS BY STATE	DISTRIBUTORS' AND DEALERS' LICENSES	INSPECTION FEES 3/	FINES AND PENALTIES	MISCELLANEOUS RECEIPTS 4/	TOTAL				
	CENTS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	
ALABAMA	6	14,415	-	14,415	-	14,415	-	61	-	-	61	14,476	-	14,476	ALABAMA
ARIZONA	5	5,189	-	5,189	744	4,445	*	-	1	-	1	4,446	-	4,446	ARIZONA
ARKANSAS	6.5	10,647	-	10,647	-	10,647	-	95	*	-	95	10,742	-	10,742	ARKANSAS
CALIFORNIA	3	54,353	-	54,353	4,558	49,795	15	-	-	1	16	49,811	-	49,811	CALIFORNIA
COLORADO	4	8,961	-	8,961	1,210	7,751	-	-	-	-	-	7,751	-	7,751	COLORADO
CONNECTICUT	3	10,193	51	10,142	232	9,910	51	-	-	-	51	9,961	-	9,961	CONNECTICUT
DELAWARE	4	2,288	-	2,288	145	2,143	3	-	-	-	3	2,146	-	2,146	DELAWARE
FLORIDA	7	24,323	-	24,323	-	24,323	34	410	-	-	444	24,767	-	24,767	FLORIDA
GEORGIA	6	21,264	210	21,054	-	21,054	34	-	-	-	34	21,088	-	21,088	GEORGIA
IDAHO	5/ 5.1	4,892	-	4,892	425	4,467	*	-	-	1	1	4,468	4	4,464	IDAHO
ILLINOIS	3	43,159	863	42,296	3,296	39,000	-	399	1	-	400	39,400	-	39,400	ILLINOIS
INDIANA	4	25,845	-	25,845	2,020	23,825	*	492	-	1	493	24,318	-	24,318	INDIANA
IOWA	3	16,432	-	16,432	2,461	13,971	62	-	-	-	62	14,033	-	14,033	IOWA
KANSAS	3	10,023	-	10,023	-	10,023	15	106	-	35	156	10,179	-	10,179	KANSAS
KENTUCKY	5	13,974	140	13,834	-	13,834	-	-	2	-	2	13,836	-	13,836	KENTUCKY
LOUISIANA	7	17,381	-	17,381	*	17,381	-	82	*	-	6/ 82	17,463	-	17,463	LOUISIANA
MAINE	4	5,946	-	5,946	224	5,722	-	-	*	-	*	5,722	4	5,718	MAINE
MARYLAND	4	11,447	-	11,447	809	10,638	-	-	-	-	-	10,638	-	10,638	MARYLAND
MASSACHUSETTS	3	21,548	-	21,548	1,036	20,512	-	-	*	-	*	20,512	-	20,512	MASSACHUSETTS
MICHIGAN	3	31,409	-	31,409	1,579	29,830	5	-	7	-	12	29,842	48	29,794	MICHIGAN
MINNESOTA	4	21,216	-	21,216	2,570	18,646	1	160	2	4	167	18,813	-	18,813	MINNESOTA
MISSISSIPPI 7/	6	11,735	-	11,735	426	11,309	-	-	-	-	-	11,309	-	11,309	MISSISSIPPI 7/
MISSOURI	2	12,757	-	12,757	661	12,096	-	131	7	-	138	12,234	-	12,234	MISSOURI
MONTANA	5	5,887	-	5,887	1,087	4,800	-	7	-	-	7	4,807	-	4,807	MONTANA
NEBRASKA	5	11,828	89	11,739	258	11,481	9	112	-	33	154	11,635	50	11,585	NEBRASKA
NEVADA	4	1,459	28	1,431	95	1,336	*	23	*	-	23	1,359	-	1,359	NEVADA
NEW HAMPSHIRE	4	3,643	-	3,643	135	3,508	-	-	*	-	*	3,508	-	3,508	NEW HAMPSHIRE
NEW JERSEY	3	25,162	-	25,162	2,156	23,006	61	-	1	-	62	23,068	-	23,068	NEW JERSEY
NEW MEXICO	5	4,758	-	4,758	463	4,295	25	-	-	-	25	4,320	-	4,320	NEW MEXICO
NEW YORK	4	72,866	728	72,138	2,445	69,693	64	-	-	*	64	69,757	-	69,757	NEW YORK
NORTH CAROLINA	6	25,149	-	25,149	617	24,532	-	1,017	-	7	1,024	25,556	-	25,556	NORTH CAROLINA
NORTH DAKOTA	8/ 4	3,485	52	3,433	785	2,648	1	66	-	21	88	2,736	-	2,736	NORTH DAKOTA
OHIO	4	9/ 52,656	-	52,656	2,190	50,466	-	-	-	-	-	50,466	-	50,466	OHIO
OKLAHOMA	4	15,258	305	14,953	747	14,206	-	284	5	-	289	14,495	-	14,495	OKLAHOMA
OREGON	5	12,010	-	12,010	1,419	10,591	-	-	*	-	*	10,591	9	10,582	OREGON
PENNSYLVANIA	4	60,256	672	59,584	-	59,584	-	-	6	-	6	59,590	-	59,590	PENNSYLVANIA
RHODE ISLAND	3	4,257	-	4,257	230	4,027	4	-	-	-	4	4,031	-	4,031	RHODE ISLAND
SOUTH CAROLINA	6	12,562	-	12,562	265	12,297	-	250	-	-	250	12,547	31	12,516	SOUTH CAROLINA
SOUTH DAKOTA	4	5,247	107	5,140	1,184	3,956	-	67	-	-	67	4,023	11	4,012	SOUTH DAKOTA
TENNESSEE	7	18,853	-	18,853	97	18,756	-	1,018	-	58	1,076	19,832	105	19,727	TENNESSEE
TEXAS	4	52,939	530	52,409	7,220	45,189	-	-	-	19	19	45,208	-	45,208	TEXAS
UTAH	4	3,793	58	3,735	-	3,735	1	-	*	*	1	3,736	48	3,688	UTAH
VERMONT	4	2,679	-	2,679	-	2,679	-	-	*	-	*	2,679	-	2,679	VERMONT
VIRGINIA	5	19,005	-	19,005	1,174	17,831	*	-	1	-	1	17,832	3	17,829	VIRGINIA
WASHINGTON	5	17,227	-	17,227	1,233	15,994	3	-	-	9	12	16,006	-	16,006	WASHINGTON
WEST VIRGINIA	5	10,560	-	10,560	151	10,409	14	-	-	-	14	10,423	-	10,423	WEST VIRGINIA
WISCONSIN	4	21,949	-	21,949	1,678	20,271	-	167	-	-	167	20,438	-	20,438	WISCONSIN
WYOMING	4	2,622	-	2,622	-	2,622	2	-	-	-	2	2,624	44	2,580	WYOMING
DISTRICT OF COLUMBIA	2	2,805	-	2,805	21	2,784	7	-	-	-	7	2,791	-	2,791	DISTRICT OF COLUMBIA
TOTAL	10/ 3.96	868,312	3,833	864,479	48,046	816,433	411	4,947	33	189	5,580	822,013	357	821,656	TOTAL

1/ THE STATES FOR WHICH AMOUNTS ARE SHOWN MAKE ALLOWANCES TO DISTRIBUTORS FOR EXPENSE OF COLLECTING THE TAX. IN CONNECTICUT, KENTUCKY, SOUTH DAKOTA, AND UTAH ALLOWANCES OF 1, 2 1/4, 4, AND 3 PERCENT, RESPECTIVELY, OF THE TAX OTHERWISE DUE ARE MADE IN CONSIDERATION OF BOTH EXPENSE OF COLLECTION AND GALLONAGE LOSSES IN HANDLING. IN THESE STATES THE ALLOWANCES FOR EXPENSES ONLY HAVE BEEN ESTIMATED AS ½, 1, 2, AND 1½ PERCENT, RESPECTIVELY.

2/ STARS INDICATE AMOUNTS LESS THAN $500.

3/ FEES FOR INSPECTION OF MOTOR-VEHICLE FUEL. WHEREVER POSSIBLE, FEES FOR INSPECTION OF KEROSENE AND OTHER NON-MOTOR-VEHICLE FUELS HAVE BEEN ELIMINATED.

4/ INCLUDES FEES FOR MOTOR-FUEL CARRIER PERMITS, REFUND OR EXEMPTION PERMITS, AND MISCELLANEOUS UNCLASSIFIED RECEIPTS.

5/ RATE CHANGED FROM 5 CENTS TO 5.1 CENTS MARCH 11.

6/ RECEIPTS FROM TAX ON LUBRICATING OIL, $853,000, NOT INCLUDED IN THIS TABLE.

7/ SPECIAL COUNTY TAXES OF 3 CENTS PER GALLON IN HANCOCK COUNTY AND 2 CENTS PER GALLON IN HARRISON COUNTY, AMOUNTING TO $175,000 IN 1939, ARE IMPOSED FOR SEAWALL PROTECTION AND ARE NOT INCLUDED IN THIS TABLE.

8/ RATE CHANGED FROM 3 CENTS TO 4 CENTS JULY 1.

9/ OHIO IMPOSES A 3-CENT TAX ON MOTOR-VEHICLE FUEL AND A 1-CENT TAX ON ALL LIQUID FUELS. THE RECEIPTS FROM THE 1-CENT TAX APPLICABLE TO NON-MOTOR-VEHICLE FUELS (KEROSENE, FUEL OIL, ETC.) WERE $641,000. THESE RECEIPTS HAVE BEEN ELIMINATED FROM THE TOTAL GIVEN, WHICH REPRESENTS A 4-CENT TAX ON MOTOR-VEHICLE FUEL.

10/ WEIGHTED AVERAGE RATE.

STATE MOTOR-VEHICLE REGISTRATIONS-1939

COMPILED FOR CALENDAR YEAR FROM REPORTS OF STATE AUTHORITIES 1/

TABLE MV-1, 1939
ISSUED MAY 1940

STATE	TOTAL REGISTERED MOTOR VEHICLES, PUBLIC, PRIVATE AND COMMERCIAL 2/	PRIVATE AND COMMERCIAL VEHICLES 3/ — MOTOR VEHICLES: TOTAL MOTOR VEHICLES	PASSENGER MOTOR VEHICLES: TOTAL	PASSENGER MOTOR VEHICLES: AUTOMOBILES (INCLUDING TAXICABS)	PASSENGER MOTOR VEHICLES: MOTOR BUSSES 4/	MOTOR TRUCKS, TRACTOR TRUCKS, ETC.	OTHER REGISTERED VEHICLES: TRAILERS AND SEMI-TRAILERS 5/	OTHER REGISTERED VEHICLES: MOTOR-CYCLES	PUBLICLY OWNED VEHICLES — FEDERAL 6/: MOTOR VEHICLES	FEDERAL 6/: TRAILERS AND SEMI-TRAILERS	FEDERAL 6/: MOTOR-CYCLES	STATE, COUNTY, AND MUNICIPAL 7/: MOTOR VEHICLES	STATE, COUNTY, AND MUNICIPAL 7/: TRAILERS AND SEMI-TRAILERS	STATE, COUNTY, AND MUNICIPAL 7/: MOTOR-CYCLES	DEALERS' REGISTRATIONS AND PLATES 8/: REGULAR REGIS-TRATIONS	DEALERS' REGISTRATIONS AND PLATES 8/: EXTRA SETS OF PLATES	1938 TOTAL REGISTERED MOTOR VEHICLES, PRIVATE AND COMMERCIAL ONLY	YEAR'S CHANGE IN PRIVATE AND COMMERCIAL MOTOR-VEHICLE REGISTRATIONS: INCREASE OR DECREASE	YEAR'S CHANGE: PER-CENT-AGE CHANGE	STATE
ALABAMA	331,742	325,472	266,582	262,847	3,735	58,890	4,574	1,013	2,060	52	6	4,210	-	-	3,150	-	301,990	23,482	7.8	ALABAMA
ARIZONA	136,037	131,355	107,272	106,924	348	24,083	4,628	440	2,533	88	3	2,149	178	18	285	1,372	128,791	2,564	2.0	ARIZONA
ARKANSAS	245,707	241,425	181,052	180,555	497	60,373	10,707	549	2,143	37	5	2,139	23	25	561	-	220,391	21,034	9.5	ARKANSAS
CALIFORNIA	2,642,006	2,606,590	2,298,608	2,298,608	(9/)	307,982	155,316	13,271	8,818	332	76	26,598	1,766	1,189	4,591	-	2,510,867	95,723	3.8	CALIFORNIA
COLORADO	345,884	343,487	286,913	285,787	1,126	56,574	1,574	1,355	2,397	29	8	-	-	-	3,858	-	332,774	10,713	3.2	COLORADO
CONNECTICUT	465,346	460,870	387,299	386,131	1,168	73,571	5,951	2,008	700	20	14	3,776	171	308	2,957	8,176	440,335	20,535	4.7	CONNECTICUT
DELAWARE	69,109	67,992	56,744	56,744	(9/)	11,248	3,047	280	372	7	-	745	42	-	747	-	64,078	3,914	6.1	DELAWARE
FLORIDA	458,615	451,357	378,116	376,707	1,409	73,241	18,793	1,630	1,851	36	18	5,407	343	161	2,729	-	423,021	28,336	6.7	FLORIDA
GEORGIA	477,713	469,440	387,489	384,773	2,716	81,951	13,617	1,473	3,475	113	32	4,798	77	120	420	2,166	432,360	37,080	8.6	GEORGIA
IDAHO	156,820	153,226	121,714	121,589	125	31,512	21,513	612	1,913	47	1	1,681	108	11	388	-	137,851	15,375	11.2	IDAHO
ILLINOIS	1,863,486	1,849,623	1,624,031	1,624,031	(9/)	225,592	24,966	6,525	3,909	136	29	9,954	330	702	4,363	-	1,780,865	68,758	3.9	ILLINOIS
INDIANA	969,593	960,842	824,196	822,942	1,254	136,646	71,584	5,192	2,137	141	21	6,614	-	192	2,587	-	922,788	38,054	4.1	INDIANA
IOWA	774,227	766,412	671,858	671,858	(9/)	94,554	10/ 98,292	2,753	1,605	38	12	6,210	410	73	1,941	4,497	740,021	26,391	3.6	IOWA
KANSAS	575,980	574,472	475,856	475,464	392	98,616	5,795	1,251	1,508	78	15	-	-	-	2,068	-	573,985	487	0.1	KANSAS
KENTUCKY	444,218	437,188	367,903	367,236	667	69,285	(11/)	1,181	2,582	88	98	4,448	-	-	782	-	414,207	22,981	5.5	KENTUCKY
LOUISIANA	346,820	340,091	263,188	260,145	3,043	76,903	13,673	1,264	1,916	59	11	4,813	355	69	326	-	326,199	13,892	4.3	LOUISIANA
MAINE	203,793	200,867	157,605	157,426	179	43,262	12/ 10,658	796	640	22	10	2,286	181	38	743	-	196,690	4,177	2.1	MAINE
MARYLAND	430,095	425,064	365,376	364,323	1,053	59,688	4,641	1,605	2,808	86	20	2,223	-	-	8,679	-	395,347	29,717	7.5	MARYLAND
MASSACHUSETTS	874,932	871,936	765,656	760,838	4,818	106,280	14,585	712	2,996	84	38	(13/)	-	200	3,253	18,904	843,789	28,147	3.3	MASSACHUSETTS
MICHIGAN	1,475,616	1,472,311	1,326,808	14/ 1,325,918	890	145,503	154,262	4,619	3,305	128	26	-	-	-	1,903	1,903	1,408,835	63,476	4.5	MICHIGAN
MINNESOTA	848,572	840,050	721,473	720,912	561	118,577	42,175	2,324	3,221	120	19	5,301	-	-	1,791	-	821,241	18,809	2.3	MINNESOTA
MISSISSIPPI	248,789	244,086	186,989	185,475	1,514	57,097	4,149	409	1,940	42	1	2,763	-	45	2,823	-	215,195	28,891	15/ 13.4	MISSISSIPPI
MISSOURI	881,946	877,094	735,485	734,894	591	141,609	34,317	2,299	2,606	57	9	2,246	-	9	2,289	3,282	837,118	39,976	4.8	MISSOURI
MONTANA	185,327	180,319	135,839	135,839	(9/)	44,480	4,195	503	2,579	49	1	2,429	55	-	952	-	171,326	8,993	5.2	MONTANA
NEBRASKA	411,464	406,905	343,879	343,563	316	63,026	43,473	1,244	1,238	17	7	3,321	447	52	1,440	1,993	407,330	-425	-0.1	NEBRASKA
NEVADA	42,296	40,771	32,781	32,586	195	7,990	1,361	139	846	15	1	679	33	8	71	275	38,424	2,347	6.1	NEVADA
NEW HAMPSHIRE	131,963	131,302	102,644	102,409	235	28,658	5,708	817	661	33	4	-	-	-	573	-	124,379	6,923	5.6	NEW HAMPSHIRE
NEW JERSEY	1,041,337	1,027,747	894,061	889,081	4,980	133,686	7,679	4,822	3,047	88	27	10,543	-	523	2,470	11,823	1,000,684	27,063	2.7	NEW JERSEY
NEW MEXICO	123,549	120,441	91,953	91,476	477	28,488	2,762	379	1,995	87	3	1,113	-	38	161	67	116,537	3,904	3.4	NEW MEXICO
NEW YORK	2,689,288	2,655,733	2,324,451	2,315,503	8,948	331,282	46,845	11,852	6,315	193	95	27,240	964	1,070	5,289	-	2,584,123	71,610	2.8	NEW YORK
NORTH CAROLINA	587,832	573,497	486,548	485,616	932	86,949	44,882	1,797	2,210	44	2	12,125	-	-	8,705	-	537,242	36,255	6.7	NORTH CAROLINA
NORTH DAKOTA	178,161	176,501	142,523	142,384	139	33,978	984	284	906	19	2	754	-	-	542	376	174,256	2,245	1.3	NORTH DAKOTA
OHIO	1,910,468	1,886,984	1,702,761	1,702,761	(9/)	184,223	134,174	8,935	3,005	150	40	20,479	1,164	406	4,031	20,290	1,870,249	16,735	0.9	OHIO
OKLAHOMA	565,864	556,163	457,991	455,771	2,220	98,172	14,757	1,142	2,644	76	5	7,057	-	-	3,701	-	535,399	20,764	3.9	OKLAHOMA
OREGON	376,736	369,330	306,581	305,943	638	62,749	(9/)	1,693	3,191	149	16	4,215	-	-	656	812	357,321	12,009	3.4	OREGON
PENNSYLVANIA	2,082,862	2,054,787	1,803,366	1,798,032	5,334	251,421	30,738	11,238	3,873	171	44	24,202	480	960	29,917	-	1,976,466	78,321	4.0	PENNSYLVANIA
RHODE ISLAND	177,069	175,068	155,369	154,916	453	19,699	686	730	565	37	7	1,436	24	104	372	-	168,888	6,180	3.7	RHODE ISLAND
SOUTH CAROLINA	321,235	314,628	270,901	268,633	2,268	43,727	5,598	929	2,069	47	4	4,538	-	88	1,002	2,190	287,913	26,715	9.3	SOUTH CAROLINA
SOUTH DAKOTA	192,111	189,485	159,099	158,998	101	30,386	21,821	456	1,410	30	8	1,216	234	-	789	-	180,632	8,853	4.9	SOUTH DAKOTA
TENNESSEE	433,982	423,956	356,903	356,183	720	67,053	(9/)	1,758	2,451	58	2	7,575	-	-	588	-	398,624	25,332	6.4	TENNESSEE
TEXAS	1,641,662	1,618,039	1,282,398	1,281,566	832	335,641	54,514	4,562	6,230	263	47	17,393	1,172	360	3,199	-	1,548,343	69,696	4.5	TEXAS
UTAH	135,935	132,871	111,656	110,980	676	21,215	558	486	2,010	34	13	1,054	20	40	338	966	127,004	5,867	4.6	UTAH
VERMONT	91,407	90,713	81,137	81,041	96	16/ 9,576	2,026	482	694	16	1	-	-	-	612	-	87,402	3,311	3.8	VERMONT
VIRGINIA	469,518	460,416	390,498	390,498	-	69,918	9,877	2,079	3,613	235	57	5,489	61	251	5,553	-	441,462	18,954	4.3	VIRGINIA
WASHINGTON	546,435	535,799	450,305	449,333	972	85,494	20,882	2,171	3,443	171	23	7,193	363	160	1,503	3,311	523,328	12,471	2.4	WASHINGTON
WEST VIRGINIA	292,484	286,167	237,878	237,189	689	48,289	3,382	1,208	1,002	21	2	5,315	164	71	11,178	-	275,691	10,476	3.8	WEST VIRGINIA
WISCONSIN	859,173	848,658	705,751	705,135	616	142,907	5,783	3,419	2,866	115	15	7,649	212	261	2,351	-	840,291	8,367	1.0	WISCONSIN
WYOMING	84,990	82,884	64,954	64,836	118	17,930	10,795	291	1,340	43	20	766	74	-	356	-	80,765	2,119	2.6	WYOMING
DISTRICT OF COLUMBIA	167,426	164,673	150,955	149,745	1,210	13,718	788	642	1,382	31	56	17/ 1,371	77	76	2,451	-	162,863	1,810	1.1	DISTRICT OF COLUMBIA
AT LARGE	2,250	-	-	-	-	-	-	-	2,250	39	12	-	-	-	-	-	-	-	-	AT LARGE
TOTAL	31,009,870	30,615,087	26,201,395	26,142,144	59,251	4,413,692	1,193,085	117,619	121,270	4,071	986	273,513	9,528	7,628	142,034	82,403	29,485,680	1,129,407	3.8	TOTAL

1/ REGISTRATION PERIODS ENDING NOT EARLIER THAN NOVEMBER 30 AND NOT LATER THAN JANUARY 31 ARE CONSIDERED CALENDAR-YEAR PERIODS. IN THOSE STATES WHERE THE REGISTRATION PERIOD IS DEFINITELY REMOVED FROM THE CALENDAR YEAR, REGISTRATION FIGURES WERE OBTAINED FOR THE CALENDAR-YEAR PERIOD.

2/ TOTALS GIVEN IN THIS COLUMN, WHICH INCLUDE PUBLICLY OWNED AS WELL AS PRIVATE AND COMMERCIAL REGISTRATIONS, DO NOT APPEAR IN TABLES FOR PREVIOUS YEARS. PRIVATE AND COMMERCIAL REGISTRATIONS, GIVEN IN THE SECOND COLUMN, ARE COMPARABLE WITH FIRST COLUMN OF TABLE MV-1 FOR PAST YEARS. MOTOR-VEHICLE TOTALS DO NOT INCLUDE TRAILERS, SEMITRAILERS, AND MOTORCYCLES.

3/ WHEREVER POSSIBLE PUBLICLY OWNED VEHICLES AND VEHICLES NOT FOR HIGHWAY USE HAVE BEEN ELIMINATED FROM THESE COLUMNS.

4/ A COMPLETE SEGREGATION OF MOTOR BUSSES FROM OTHER VEHICLES IS NOT AVAILABLE. THE FIGURES GIVEN REPRESENT COMMON-CARRIER BUSSES IN MOST CASES, ALTHOUGH IN SOME STATES CONTRACT BUSSES AND CONTRACT SCHOOL BUSSES ARE INCLUDED. IN SOME CASES CITY BUSSES ARE NOT INCLUDED. WHERE NO BUSSES ARE TABULATED, THEY ARE INCLUDED WITH AUTOMOBILES, UNLESS OTHERWISE NOTED.

5/ FIGURES FOR TRAILERS AND SEMITRAILERS ARE AS REPORTED. APPARENT INCONSISTENCIES ARE DUE TO THE FACT THAT SOME STATES REQUIRE THE REGISTRATION OF TOURIST TRAILERS, LIGHT WORK TRAILERS, AND SIMILAR VEHICLES, WHEREAS OTHER STATES REGISTER ONLY FREIGHT-CARRYING TRAILERS AND SEMITRAILERS.

6/ DATA ON FEDERAL VEHICLES OBTAINED THROUGH AGENCY OF PROCUREMENT DIVISION, DEPARTMENT OF THE TREASURY.

7/ STATE, COUNTY, AND MUNICIPAL VEHICLES ARE INCLUDED WITH PRIVATE AND COMMERCIAL REGISTRATIONS IN COLORADO, KANSAS, MICHIGAN, NEW HAMPSHIRE, AND VERMONT. A SMALL NUMBER OF FEDERAL VEHICLES ARE INCLUDED IN THE FIGURES FOR INDIANA, KENTUCKY, LOUISIANA, MONTANA, NEBRASKA, NEW YORK, PENNSYLVANIA, AND VIRGINIA.

8/ FIGURES INCLUDE NEW-CAR, USED-CAR, AND MOTORCYCLE DEALERS' REGISTRATIONS AND SOME WRECKER AND REPAIRER REGISTRATIONS. DATA ON DEALERS' EXTRA PLATES ARE INCOMPLETE, ALTHOUGH THEY ARE INCLUDED WITH DEALERS' REGISTRATIONS IN SOME STATES.

9/ INCLUDED WITH MOTOR TRUCKS.

10/ INCLUDES 68,985 LIGHT TRAILERS REGISTERED WITHOUT CHARGE.

11/ TRAILERS OF 1,000 POUNDS CAPACITY OR MORE PROHIBITED ON HIGHWAYS, ALTHOUGH PERMITTED IN CITIES UNDER CITY LICENSES. TRACTOR-SEMITRAILERS REGISTERED AS MOTOR TRUCKS. LIGHT TRAILERS PERMITTED BUT NOT REGISTERED.

12/ INCLUDES LIGHT TRAILERS AND COMMERCIAL SEMITRAILERS. COMMERCIAL FULL TRAILERS INCLUDED WITH MOTOR TRUCKS.

13/ APPROXIMATELY 7,500, BUT CANNOT BE SEGREGATED BY TYPE FROM PRIVATE AND COMMERCIAL VEHICLES.

14/ TAXICABS INCLUDED WITH MOTOR TRUCKS.

15/ LARGE INCREASE IS DUE IN PART TO FACT THAT 1938 FIGURES WERE FOR A TEN-MONTH REGISTRATION PERIOD BECAUSE OF CHANGE IN LICENSE YEAR.

16/ TRUCKS UNDER 1,500 POUNDS CAPACITY INCLUDED WITH PASSENGER CARS.

17/ INCLUDES 399 AUTOMOBILES OF THE DIPLOMATIC CORPS.

STATE MOTOR-VEHICLE RECEIPTS-1939

COMPILED FOR CALENDAR YEAR FROM REPORTS OF STATE AUTHORITIES 1/

TABLE MV-2, 1939
ISSUED MAY 1940

STATE	TOTAL RECEIPTS, REGISTRATION AND OTHER FEES	MOTOR-VEHICLE REGISTRATION FEES: TOTAL 2/	PASSENGER MOTOR VEHICLES: TOTAL	PASSENGER MOTOR VEHICLES: AUTOMOBILES (INCLUDING TAXICABS)	PASSENGER MOTOR VEHICLES: MOTOR BUSSES 3/	MOTOR TRUCKS, TRACTOR TRUCKS, ETC.	REGISTRATION FEES, OTHER VEHICLES: TRAILERS AND SEMI-TRAILERS	REGISTRATION FEES, OTHER VEHICLES: MOTORCYCLES	TOTAL REGISTRATION FEES, ALL VEHICLES	MISCELLANEOUS RECEIPTS: TOTAL	DEALERS' LICENSES AND PLATES	OPERATORS' AND CHAUFFEURS' PERMITS	CERTIFICATES OF TITLE	SPECIAL TITLING TAXES 4/	FINES AND PENALTIES	TRANSFER OR REREGISTRATION FEES	OTHER RECEIPTS	ESTIMATED SERVICE CHARGES, LOCAL COLLECTORS 5/	UNCLASSIFIED REFUNDS	STATE
	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	1,000 DOLLARS	
ALABAMA	4,947	4,186	3,160	3,088	72	1,026	52	4	4,242	705	3	524	-	-	168	-	10	-	-	ALABAMA
ARIZONA	1,134	826	397	371	26	429	76	2	904	230	5	25	70	-	5	13	112	-	-	ARIZONA
ARKANSAS	3,140	2,684	1,741	1,665	76	943	171	1	2,856	284	87	183	-	-	3	8	3	-	-	ARKANSAS
CALIFORNIA 6/	24,646	21,503	16,880	16,880	(7/)	4,623	1,064	66	22,633	2,013	83	111	-	-	181	1,378	260	-	-	CALIFORNIA 6/
COLORADO	2,879	2,109	1,631	1,631	-	8/ 478	35	2	2,146	733	29	344	173	-	38	81	68	-	-	COLORADO
CONNECTICUT	6,738	4,456	2,947	2,819	128	1,509	21	6	4,483	2,255	109	1,752	-	-	147	128	125	-	-6	CONNECTICUT
DELAWARE	1,313	943	645	645	(7/)	298	35	1	979	334	7	142	40	-	104	17	24	-	-	DELAWARE
FLORIDA	7,096	6,196	4,310	4,115	195	1,886	314	8	6,518	578	23	210	213	-	-	1	13	118	-	FLORIDA
GEORGIA	2,620	1,612	1,075	958	117	537	218	2	1,832	788	13	734	-	-	-	9	32	-	-	GEORGIA
IDAHO	1,399	1,139	618	609	9	521	64	2	1,205	194	23	129	32	-	-	-	10	-	-	IDAHO
ILLINOIS	24,352	21,152	14,706	14,706	(7/)	6,446	199	17	21,368	2,984	94	1,668	512	-	2	505	232	-	-29	ILLINOIS
INDIANA	10,001	8,020	6,222	6,132	90	1,798	370	10	8,400	1,601	49	674	324	-	32	342	55	261	-136	INDIANA
IOWA	12,624	11,674	8,818	8,818	(7/)	2,856	106	10	11,790	834	62	635	-	-	-	215	12	-	-90	IOWA
KANSAS	4,363	3,587	2,723	2,703	20	864	79	5	3,671	692	31	372	127	-	113	24	25	-	-	KANSAS
KENTUCKY	4,960	3,088	1,855	1,744	111	1,233	(9/)	2	3,090	1,870	23	528	-	1,099	4	202	14	-	-	KENTUCKY
LOUISIANA	5,309	4,524	3,178	3,074	104	1,346	714	5	5,243	66	11	110	-	-	-	-	5	-	-60	LOUISIANA
MAINE	3,788	2,857	1,990	1,972	18	867	10/ 70	4	2,931	857	59	555	38	-	24	139	42	-	-	MAINE
MARYLAND	5,538	3,802	3,161	2,985	176	641	136	6	3,944	1,594	45	312	196	644	283	125	42	-	-53	MARYLAND
MASSACHUSETTS	7,028	4,304	2,857	2,715	142	1,447	20	1	4,325	2,703	66	2,629	-	-	2	-	70	-	-64	MASSACHUSETTS
MICHIGAN	22,119	18,685	13,221	11/ 13,221	(7/)	5,464	1,136	17	19,838	2,281	91	854	780	-	-	319	237	-	-	MICHIGAN
MINNESOTA	9,884	9,089	7,124	6,975	149	1,965	291	8	9,388	496	58	177	-	-	112	-	149	-	-	MINNESOTA
MISSISSIPPI	2,567	2,522	-	-	-	-	-	-	2,522	45	3	-	-	-	36	-	6	-	-	MISSISSIPPI
MISSOURI	10,226	8,690	7,279	7,279	(7/)	1,411	156	12	8,858	1,368	83	457	455	-	2	306	65	-	-	MISSOURI
MONTANA 12/	1,634	1,233	890	890	(7/)	343	18	1	1,252	382	19	180	66	-	70	41	6	-	-	MONTANA 12/
NEBRASKA	2,683	2,139	1,275	1,250	25	864	59	2	2,200	483	29	298	51	-	-	72	36	-	-3	NEBRASKA
NEVADA	286	262	164	163	1	98	6	1	269	17	2	-	-	-	1	12	2	-	-	NEVADA
NEW HAMPSHIRE	2,962	2,469	-	-	-	-	-	4	2,473	489	24	367	-	-	51	-	47	-	-	NEW HAMPSHIRE
NEW JERSEY	21,312	14,541	10,401	10,104	297	4,140	337	10	14,888	6,424	71	4,023	559	-	234	562	985	-	-10	NEW JERSEY
NEW MEXICO	1,909	1,601	1,025	969	56	576	47	1	1,649	260	10	155	27	-	1	-	67	-	-	NEW MEXICO
NEW YORK	48,432	44,747	32,683	32,683	-	12,064	654	49	45,450	2,982	203	904	-	-	463	1,077	359	-	-24	NEW YORK
NORTH CAROLINA	8,163	7,797	4,608	4,539	69	3,189	(7/)	7	7,804	359	33	130	168	-	67	-	12	-	-51	NORTH CAROLINA
NORTH DAKOTA	1,619	1,421	1,095	1,080	15	326	4	2	1,427	192	15	98	57	19	-	-	3	-	-	NORTH DAKOTA
OHIO	28,625	23,259	15,142	15,142	(7/)	8,117	1,308	42	24,609	4,016	246	776	513	-	60	678	32	1,711	-	OHIO
OKLAHOMA	6,046	4,458	2,731	2,627	104	1,727	218	6	4,682	1,364	45	605	287	-	-	-	130	297	-	OKLAHOMA
OREGON	3,469	2,729	1,568	1,530	38	1,161	(7/)	5	2,734	735	25	473	188	-	24	-	25	-	-	OREGON
PENNSYLVANIA	36,563	28,680	19,955	19,395	560	8,725	458	31	29,169	7,394	386	3,140	2,053	-	12	1,460	376	-	-33	PENNSYLVANIA
RHODE ISLAND	2,929	2,324	1,818	1,774	44	506	3	3	2,330	599	17	441	-	-	-	87	54	-	-	RHODE ISLAND
SOUTH CAROLINA	1,915	1,505	821	821	-	684	126	1	1,632	283	26	199	-	-	27	27	43	-	-39	SOUTH CAROLINA
SOUTH DAKOTA	2,165	1,631	1,394	1,390	4	237	37	1	1,669	496	19	-	26	439	-	-	12	-	-	SOUTH DAKOTA
TENNESSEE	5,443	4,647	-	-	-	-	-	-	4,647	796	(13/)	568	-	-	108	-	121	-	-1	TENNESSEE
TEXAS	21,194	19,641	12,631	12,479	152	7,010	587	19	20,247	947	39	417	-	-	-	334	157	-	-	TEXAS
UTAH	1,176	1,012	531	531	(7/)	481	(7/)	1	1,013	163	13	22	72	-	1	21	34	-	-	UTAH
VERMONT	2,490	2,089	1,472	14/ 1,459	13	14/ 617	33	4	2,126	364	27	289	-	-	-	51	7	-	-10	VERMONT
VIRGINIA	6,847	5,740	4,328	4,328	-	1,412	150	6	5,896	951	61	384	298	-	-	173	37	-	-2	VIRGINIA
WASHINGTON	4,560	2,563	1,420	1,420	-	1,143	252	6	2,821	1,739	14	1,284	146	-	33	87	15	160	-	WASHINGTON
WEST VIRGINIA	5,974	4,734	3,630	3,606	24	1,104	58	5	4,797	1,177	45	268	150	648	-	56	10	-	-	WEST VIRGINIA
WISCONSIN	12,954	12,287	9,376	9,135	241	2,911	379	16	12,682	272	10	35	-	-	-	216	11	-	-	WISCONSIN
WYOMING	622	570	369	369	-	201	37	1	608	14	8	-	-	-	-	5	1	-	-	WYOMING
DISTRICT OF COLUMBIA	1,851	1,270	862	848	14	408	20	3	1,293	558	(15/)	262	83	-	-	35	178	-	-	DISTRICT OF COLUMBIA
PARTIAL TOTALS 16/	-	-	236,727	233,637	3,090	96,632	10,118	418	-	-	-	-	-	-	-	-	-	-	-	PARTIAL TOTALS 16/
FULL TOTALS	412,494	342,997	-	-	-	-	-	-	353,533	58,961	2,444	28,443	7,704	2,849	2,408	8,806	4,371	2,547	-611	FULL TOTALS

1/ RECEIPTS FOR REGISTRATION PERIODS ENDING NOT EARLIER THAN NOVEMBER 30 AND NOT LATER THAN JANUARY 31 ARE CONSIDERED CALENDAR-YEAR RECEIPTS. IN THOSE STATES WHERE THE REGISTRATION PERIOD IS DEFINITELY REMOVED FROM THE CALENDAR YEAR, REGISTRATION RECEIPTS WERE OBTAINED FOR THE CALENDAR-YEAR PERIOD.

2/ SEGREGATION OF REGISTRATION FEES BY TYPE OF VEHICLE WAS NOT AVAILABLE FOR MISSISSIPPI, NEW HAMPSHIRE, AND TENNESSEE. TOTAL MOTOR-VEHICLE REGISTRATION FEES IN THOSE STATES INCLUDE TRAILER AND MOTORCYCLE FEES EXCEPT IN NEW HAMPSHIRE, FOR WHICH MOTORCYCLE FEES WERE REPORTED SEPARATELY. DEALERS' LICENSE FEES IN TENNESSEE AND THE DISTRICT OF COLUMBIA ARE ALSO INCLUDED IN THIS COLUMN.

3/ THE MOTOR-BUS REGISTRATION FEES ARE INCOMPLETE (SEE TABLE MV-1, 1939, NOTE 4). WHERE NO FEES ARE TABULATED, THE FEES OF BUSSES ARE INCLUDED WITH THOSE OF AUTOMOBILES, UNLESS OTHERWISE NOTED.

4/ PROCEEDS OF SPECIAL EXCISE AND PRIVILEGE TAXES ON NEW CAR SALES HAVE BEEN SEGREGATED AND ENTERED IN THIS COLUMN. RECEIPTS FROM A 2 PERCENT MOTOR-VEHICLE EXCISE TAX IN OKLAHOMA, IMPOSED AS A PART OF A GENERAL SALES TAX, ARE NOT INCLUDED IN THIS TABLE. PROCEEDS OF THIS TAX WERE $1,188,000 IN 1939.

5/ IN MANY STATES COUNTY OR LOCAL OFFICERS ARE ALLOWED SERVICE CHARGES FOR ISSUING REGISTRATIONS, OPERATORS' LICENSES, ETC. IN THE MAJORITY OF CASES THESE CHARGES ARE INCLUDED IN REGISTRATION AND OTHER FEES. THE AMOUNTS SHOWN IN THIS COLUMN ARE ESTIMATES OF SERVICE CHARGES COLLECTED AND RETAINED BY LOCAL OFFICIALS AND NOT REPORTED ELSEWHERE IN THE TABLE.

6/ REGISTRATION FEES INCLUDE PROCEEDS OF STATE "VEHICLE LICENSE FEES", $10,994,000, IMPOSED IN ADDITION TO THE REGULAR REGISTRATION FEES OF $11,639,000.

7/ INCLUDED WITH MOTOR-TRUCK FEES.

8/ FEES OF 25,934 LIGHT TRUCKS INCLUDED WITH THOSE OF PASSENGER VEHICLES.

9/ TRAILERS OF 1,000 POUNDS CAPACITY OR MORE PROHIBITED ON HIGHWAYS, ALTHOUGH PERMITTED IN CITIES UNDER CITY LICENSES. TRACTOR-SEMITRAILERS REGISTERED AS MOTOR TRUCKS. LIGHT TRAILERS PERMITTED BUT NOT REGISTERED.

10/ FEES OF LIGHT TRAILERS AND COMMERCIAL SEMITRAILERS ONLY. FEES OF COMMERCIAL FULL TRAILERS INCLUDED WITH THOSE OF MOTOR TRUCKS.

11/ FEES OF TAXICABS INCLUDED WITH THOSE OF MOTOR TRUCKS.

12/ REGISTRATION FEES ARE COLLECTED BY COUNTIES AND STATE DOES NOT MAINTAIN COMPLETE RECORD. FIGURES GIVEN ARE ESTIMATES SUPPLIED BY STATE.

13/ INCLUDED WITH MOTOR-VEHICLE REGISTRATION FEES.

14/ FEES OF TRUCKS UNDER 1,500 POUNDS CAPACITY INCLUDED WITH THOSE OF PASSENGER CARS.

15/ INCLUDED WITH PASSENGER CAR FEES.

16/ TOTALS OF COLUMNS FOR WHICH FULLY CLASSIFIED DATA WERE NOT AVAILABLE FOR ALL STATES.

STATUS OF FEDERAL-AID HIGHWAY PROJECTS

AS OF MAY 31, 1940

STATE	COMPLETED DURING CURRENT FISCAL YEAR			UNDER CONSTRUCTION			APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR PROGRAMMED PROJECTS
	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	
Alabama	$ 6,784,354	$ 3,305,842	283.7	$ 6,808,072	$ 3,651,252	224.1	$ 1,496,570	$ 745,980	63.1	$ 3,484,641
Arizona	2,393,890	1,665,440	127.7				86,950	46,480	5.2	1,794,775
Arkansas	5,117,999	4,022,344	235.2	2,093,534	1,118,170	91.0	1,053,828	521,267	53.0	1,525,366
California	5,910,428	3,129,390	92.2	7,044,277	3,692,573	123.4	2,318,266	1,178,000	53.5	4,036,664
Colorado	3,925,877	2,114,735	89.3	1,923,528	1,082,242	55.2	643,519	277,474	28.6	3,207,225
Connecticut	1,343,854	666,370	16.1	1,687,715	836,108	14.7	873,077	412,448	6.7	1,261,963
Delaware	938,628	448,701	31.5	1,036,072	518,036	7.0	898,058	421,214	22.7	1,176,866
Florida	3,640,769	1,817,537	41.7	3,678,731	1,833,246	114.7	822,431	406,692	11.4	2,461,417
Georgia	4,805,674	2,265,761	240.0	5,555,867	2,777,933	305.1	3,165,524	1,582,762	92.4	6,586,333
Idaho	2,209,950	1,291,400	114.2	1,178,327	720,678	92.2	492,509	279,607	42.6	2,040,278
Illinois	9,392,358	4,615,898	198.8	8,028,484	4,013,647	164.0	2,350,400	1,174,470	80.4	4,567,571
Indiana	4,647,980	2,237,814	88.9	6,179,453	3,083,320	130.5	2,775,764	1,387,780	48.7	2,379,188
Iowa	4,084,454	1,926,642	208.5	5,180,019	2,380,967	163.3	1,902,586	898,100	57.2	1,872,989
Kansas	4,422,161	2,140,702	231.9	2,753,068	1,373,126	134.5	5,866,205	2,918,157	369.6	4,441,249
Kentucky	3,368,541	1,663,813	112.2	2,623,217	1,310,053	44.9	3,333,502	1,666,751	112.6	3,164,847
Louisiana	1,383,213	688,377	43.4	11,914,421	3,000,572	37.5	2,304,632	1,142,195	59.8	3,196,953
Maine	2,180,657	1,078,652	53.2	716,527	358,263	16.4	920,476	460,238	21.8	861,746
Maryland	2,929,809	1,401,605	39.5	1,940,276	951,820	34.6	2,343,200	798,500	22.0	1,711,366
Massachusetts	3,140,962	1,567,753	25.1	1,885,632	939,300	15.9	2,150,212	1,071,216	18.4	3,029,716
Michigan	4,956,387	2,353,044	115.5	5,139,627	2,481,812	164.3	6,204,305	3,102,153	166.8	1,902,050
Minnesota	5,950,627	2,920,578	389.7	4,731,155	2,347,627	282.9	2,503,347	1,251,080	197.6	4,682,926
Mississippi	6,030,168	2,102,799	261.5	6,310,428	2,762,315	273.0	1,783,160	769,862	111.6	2,525,046
Missouri	4,126,910	2,040,405	163.8	4,501,580	2,239,630	151.8	5,096,484	1,890,960	160.6	5,604,260
Montana	3,393,236	1,912,298	200.2	3,807,767	2,156,592	237.7	1,304,973	665,447	93.3	4,293,771
Nebraska	4,830,793	2,332,962	418.0	5,449,599	2,611,385	585.6	2,323,162	1,158,406	332.1	3,277,363
Nevada	1,185,255	1,001,138	57.8	1,394,584	1,199,549	69.6	156,361	136,314	5.0	1,659,566
New Hampshire	814,656	400,642	27.3	1,130,306	555,210	26.2	1,073,658	421,773	21.6	911,349
New Jersey	1,695,210	836,371	15.5	5,564,998	2,782,269	41.8	172,620	86,310		2,145,319
New Mexico	2,552,381	1,552,866	184.9	1,501,097	931,624	90.3	450,009	271,265	55.1	1,931,204
New York	8,719,032	4,197,566	168.5	13,321,897	6,502,532	200.6	3,459,900	1,441,320	48.0	4,184,990
North Carolina	5,750,955	2,859,046	353.3	5,330,166	2,664,742	244.4	1,418,894	709,425	78.3	2,547,186
North Dakota	291,677	154,462	41.7	2,389,943	1,360,324	159.9	2,187,610	1,168,948	233.2	4,417,093
Ohio	6,184,561	3,032,828	86.8	11,977,902	5,965,517	106.1	4,737,350	2,367,775	46.8	5,748,730
Oklahoma	3,653,106	1,934,468	150.7	2,774,235	1,470,047	72.1	2,896,670	1,512,083	141.0	4,235,272
Oregon	3,033,397	1,815,819	113.1	3,886,202	2,208,762	162.5	281,070	165,158	11.3	1,839,645
Pennsylvania	9,609,944	4,717,728	113.7	9,175,583	4,410,784	88.3	6,279,282	3,102,189	62.4	3,805,406
Rhode Island	672,284	325,167	7.8	1,181,937	590,000	11.6	561,095	280,016	5.8	1,009,730
South Carolina	2,756,188	1,236,308	86.6	2,064,007	988,239	126.5	942,963	441,060	108.8	2,635,202
South Dakota	3,390,132	1,870,120	329.2	3,278,840	1,864,180	393.5	2,407,120	1,431,640	322.3	3,464,881
Tennessee	5,182,969	2,511,833	112.7	2,925,700	1,462,850	66.0	1,620,332	810,166	65.4	4,353,971
Texas	14,794,950	7,269,888	763.4	10,263,939	5,082,124	547.9	1,249,075	597,050	66.4	8,497,102
Utah	2,607,850	1,819,663	122.3	860,730	630,957	50.8	612,700	422,547	38.2	1,199,173
Vermont	738,188	348,926	18.4	1,250,998	625,287	38.6	324,040	155,444	5.2	500,398
Virginia	2,511,751	1,242,524	82.2	3,117,371	1,493,696	71.8	689,674	323,547	17.2	2,431,360
Washington	2,501,685	1,270,615	39.6	3,818,299	2,008,429	59.3	1,183,093	629,800	34.0	1,181,745
West Virginia	2,231,182	1,165,064	53.0	1,809,850	897,710	50.2	2,840,440	1,343,373	79.2	1,871,863
Wisconsin	5,150,897	2,525,683	187.6	5,023,976	2,465,950	153.2	1,171,333	573,890	41.7	3,915,134
Wyoming	1,562,428	953,356	141.3	1,888,836	1,199,453	195.9	65,301	41,223	10.9	1,437,863
District of Columbia	708,480	351,590	5.5	173,224	86,612	1.8	427,200	177,488	3.3	432,435
Hawaii	705,318	308,866	5.9	628,220	315,397	13.7	433,940	215,300	7.7	1,614,698
Puerto Rico	736,989	351,635	14.0	1,306,457	646,785	25.3	138,912	67,545	3.0	869,455
TOTALS	191,651,144	97,765,034	7,104.6	200,206,673	98,649,696	6,532.7	92,793,782	45,119,888	3,743.5	143,927,339

STATUS OF FEDERAL-AID SECONDARY OR FEEDER ROAD PROJECTS

AS OF MAY 31, 1940

STATE	COMPLETED DURING CURRENT FISCAL YEAR			UNDER CONSTRUCTION			APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR PROGRAMMED PROJECTS
	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	
Alabama	$ 1,081,969	$ 430,989	48.3	$ 526,612	$ 262,480	18.9	$ 432,650	$ 215,150	35.5	$ 629,332
Arizona	327,954	233,525	35.8	155,799	91,426	20.7	71,045	48,750	5.8	380,652
Arkansas	981,558	827,256	95.9	119,046	78,669	8.7	173,137	86,433	20.1	279,773
California	850,189	466,095	36.1	688,043	374,998	32.8	149,817	77,800	1.0	1,013,038
Colorado	1,115,228	568,303	37.9	54,923	8,092	.6				281,982
Connecticut	172,310	72,417	2.9	287,102	139,108	3.3	80,124	38,902	1.3	206,069
Delaware	84,115	39,067	17.5	69,537	34,768	7.8	106,095	38,808	7.7	270,667
Florida	888,923	436,084	31.3	29,916	14,958	.6	101,240	50,620	1.3	565,420
Georgia	363,706	172,132	44.2	360,339	180,170	40.5	294,117	132,059	19.4	1,287,885
Idaho	523,519	288,111	51.9	61,395	37,525	6.0				295,190
Illinois	1,549,557	691,354	93.5	1,697,985	831,818	74.1	521,700	261,000	21.7	490,107
Indiana	896,572	423,398	77.7	409,170	203,381	29.1	157,770	78,850	9.1	947,730
Iowa	609,288	291,392	160.0	1,710,242	812,860	291.9	857,161	403,569	158.9	552,219
Kansas	177,233	88,600	47.2	592,230	296,115	9.0	57,772	28,886	37.1	1,556,610
Kentucky	1,244,012	348,314	82.8	505,621	196,100	31.9	680,533	193,435	62.0	383,773
Louisiana	924,552	447,982	79.6	297,930	148,910	25.7				451,252
Maine	443,074	210,484	25.4	81,124	39,773	4.0	133,950	61,816	7.2	79,839
Maryland	306,943	144,266	20.2	97,996	48,998	3.5	58,000	28,035	4.2	437,550
Massachusetts	373,212	185,203	9.2	443,272	219,589	10.1	228,890	113,575	3.4	477,496
Michigan	1,307,287	633,561	113.8	1,253,519	630,149	80.5	487,690	243,845	53.2	682,873
Minnesota	960,455	465,774	122.3	379,975	157,400	40.1	356,745	178,373	47.8	1,261,496
Mississippi	359,900	179,919	40.7	1,063,962	520,196	52.6				713,924
Missouri	1,036,115	510,401	149.3	652,998	320,918	75.9	198,914	73,927	32.8	809,931
Montana	831,054	466,715	81.0	516,018	289,630	52.7	153,102	86,588	18.1	781,995
Nebraska	1,102,133	520,075	218.7	548,756	274,219	80.4	265,386	132,693	34.4	393,561
Nevada	164,206	134,299	25.0	197,591	169,920	25.5	54,015	47,090	14.6	181,252
New Hampshire	58,755	29,144	2.3	140,209	66,301	4.2				197,644
New Jersey	329,558	161,550	12.1	585,440	292,720	18.3				540,280
New Mexico	469,280	287,227	42.1	367,851	229,448	26.9				262,447
New York	1,818,792	872,861	91.3	2,062,718	995,315	55.5	417,741	174,171	20.7	612,569
North Carolina	1,068,033	530,556	109.6	860,823	431,828	76.1	265,100	120,364	22.3	316,132
North Dakota	114,601	59,497	8.2	62,121	34,895		156,003	83,616	3.8	1,011,462
Ohio	702,537	347,369	41.8	1,929,662	971,606	73.6	1,240,040	610,020	33.0	903,537
Oklahoma	481,426	249,832	30.1	613,296	325,546	45.6	361,500	166,695	18.8	933,839
Oregon	636,928	361,412	73.6	369,156	203,647	41.3	165,907	96,930	25.2	321,377
Pennsylvania	2,134,408	1,022,607	119.9	1,714,364	851,077	57.9	767,145	382,810	16.8	261,397
Rhode Island	93,827	46,890	2.2	230,055	115,001	3.6				95,049
South Carolina	578,846	235,287	56.9	608,940	238,145	51.9	222,119	87,732	65.5	227,321
South Dakota	16,229	8,937	4.1	14,680	9,712					1,280,913
Tennessee	956,289	420,211	32.3	114,396	57,198	7.9	42,142	21,071	3.0	1,000,026
Texas	2,799,513	1,377,896	307.1	1,178,388	577,058	163.9	290,473	137,888	44.0	1,167,078
Utah	312,283	182,505	45.5	31,870	20,500	1.2	75,730	25,000	4.0	269,807
Vermont	138,763	63,935	5.6	280,092	98,529	10.4	133,400	39,000	4.7	48,125
Virginia	680,335	326,094	66.8	537,794	242,820	30.4	91,770	28,192	4.4	360,762
Washington	581,590	301,956	43.1	414,109	217,793	32.7				384,218
West Virginia	207,328	102,063	10.2	311,219	155,084	18.4	113,508	56,754	5.7	441,349
Wisconsin	882,223	438,333	34.5	321,053	160,190	4.7	461,874	225,310	14.4	787,878
Wyoming	470,702	286,620	26.0	386,241	232,715	39.0				186,505
District of Columbia	122,504	60,900	1.5	3,192	1,096		48,200	24,100	.6	60,154
Hawaii	193,033	96,211	6.2	273,208	137,108	8.6				159,806
Puerto Rico	30,220	14,440	2.2	244,135	119,025	12.9	113,278	55,755	3.2	80,408
TOTALS	34,553,067	17,160,049	2,923.4	26,456,113	13,166,527	1,811.9	10,585,783	4,955,612	886.7	27,321,699

PUBLICATIONS of the PUBLIC ROADS ADMINISTRATION

Any of the following publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. As his office is not connected with the Agency and as the Agency does not sell publications, please send no remittance to the Federal Works Agency.

ANNUAL REPORTS

Report of the Chief of the Bureau of Public Roads, 1931. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1933. 5 cents.

Report of the Chief of the Bureau of Public Roads, 1934. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1935. 5 cents.

Report of the Chief of the Bureau of Public Roads, 1936. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1937. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1938. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1939. 10 cents.

HOUSE DOCUMENT NO. 462

Part 1 . . . Nonuniformity of State Motor-Vehicle Traffic Laws. 15 cents.

Part 2 . . . Skilled Investigation at the Scene of the Accident Needed to Develop Causes. 10 cents.

Part 3 . . . Inadequacy of State Motor-Vehicle Accident Reporting. 10 cents.

Part 4 . . . Official Inspection of Vehicles. 10 cents.

Part 5 . . . Case Histories of Fatal Highway Accidents. 10 cents.

Part 6 . . . The Accident-Prone Driver. 10 cents.

MISCELLANEOUS PUBLICATIONS

No. 76MP . . The Results of Physical Tests of Road-Building Rock. 25 cents.

No. 191MP. . Roadside Improvement. 10 cents.

No. 272MP. . Construction of Private Driveways. 10 cents.

No. 279MP. . Bibliography on Highway Lighting. 5 cents.

Highway Accidents. 10 cents.

The Taxation of Motor Vehicles in 1932. 35 cents.

Guides to Traffic Safety. 10 cents.

An Economic and Statistical Analysis of Highway-Construction Expenditures. 15 cents.

Highway Bond Calculations. 10 cents.

Transition Curves for Highways. 60 cents.

Highways of History. 25 cents.

DEPARTMENT BULLETINS

No. 1279D . . Rural Highway Mileage, Income, and Expenditures, 1921 and 1922. 15 cents.

No. 1486D . . Highway Bridge Location. 15 cents.

TECHNICAL BULLETINS

No. 55T . . . Highway Bridge Surveys. 20 cents.

No. 265T. . . Electrical Equipment on Movable Bridges. 35 cents.

Single copies of the following publications may be obtained from the Public Roads Administration upon request. They cannot be purchased from the Superintendent of Documents.

MISCELLANEOUS PUBLICATIONS

No. 296MP. . Bibliography on Highway Safety.

House Document No. 272 . . . Toll Roads and Free Roads.

Indexes to PUBLIC ROADS, volumes 6–8 and 10–19, inclusive.

SEPARATE REPRINT FROM THE YEARBOOK

No. 1036Y . . Road Work on Farm Outlets Needs Skill and Right Equipment.

TRANSPORTATION SURVEY REPORTS

Report of a Survey of Transportation on the State Highway System of Ohio (1927).

Report of a Survey of Transportation on the State Highways of Vermont (1927).

Report of a Survey of Transportation on the State Highways of New Hampshire (1927).

Report of a Plan of Highway Improvement in the Regional Area of Cleveland, Ohio (1928).

Report of a Survey of Transportation on the State Highways of Pennsylvania (1928).

Report of a Survey of Traffic on the Federal-Aid Highway Systems of Eleven Western States (1930).

UNIFORM VEHICLE CODE

Act I.—Uniform Motor Vehicle Administration, Registration, Certificate of Title, and Antitheft Act.

Act II.—Uniform Motor Vehicle Operators' and Chauffeurs' License Act.

Act III.—Uniform Motor Vehicle Civil Liability Act.

Act IV.—Uniform Motor Vehicle Safety Responsibility Act.

Act V.—Uniform Act Regulating Traffic on Highways.

Model Traffic Ordinances.

A complete list of the publications of the Public Roads Administration, classified according to subject and including the more important articles in PUBLIC ROADS, may be obtained upon request addressed to Public Roads Administration, Willard Bldg., Washington, D. C.

STATUS OF FEDERAL-AID GRADE CROSSING PROJECTS

AS OF MAY 31, 1940

STATE	COMPLETED DURING CURRENT FISCAL YEAR					UNDER CONSTRUCTION					APPROVED FOR CONSTRUCTION					BALANCE OF FUNDS AVAILABLE FOR PROGRAMMED PROJECTS
			NUMBER					NUMBER					NUMBER			
	Estimated Total Cost	Federal Aid	Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	Estimated Total Cost	Federal Aid	Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	Estimated Total Cost	Federal Aid	Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	
Alabama	$ 1,036,997	$ 1,033,332	14	2	1	$ 766,310	$ 766,227	6			$ 15,400	$ 15,400			4	$ 881,219
Arizona	317,016	316,972	1			201,045	198,841	3			2,930	2,930	1			397,816
Arkansas	182,388	182,199	3		3	824,603	820,955	4	1	4	381,594	381,152	6		7	607,550
California	1,343,969	1,339,199	10		2	1,371,661	1,192,630	6	1		25,524	25,524			11	1,701,560
Colorado	655,359	624,117	6		23	277,629	277,629	1		1	5,643	5,643			2	922,522
Connecticut	47,558	33,998			7	619,053	608,861	5	1		157,343	157,294	2			459,960
Delaware	7,839	7,839	2			20,794	20,794			4	186,356	153,408	1		12	490,500
Florida	428,094	428,094	2			196,653	192,154	2			35,832	35,832			10	1,426,798
Georgia	231,598	222,834	5		4	668,848	668,848	12	4	4	427,984	427,984	3	2	14	2,279,463
Idaho	204,578	172,785	3			345,006	314,413	4			53,156	53,156			22	452,353
Illinois	2,555,331	2,442,431	16	5	58	2,261,860	2,100,755	11	1	38	196,406	133,915			74	2,570,505
Indiana	869,394	861,372	3	1	97	806,789	806,789	5	2	42	97,172	97,172			38	1,295,880
Iowa	1,228,220	1,154,302	14		194	246,260	177,738	2		28	304,444	249,925	1		73	1,342,089
Kansas	1,000,135	992,198	12		11	795,782	795,304	11		3	185,919	185,919	1	2	13	1,272,748
Kentucky	611,305	600,627	8	4	12	995,759	995,759	9		2	233,426	233,426	5		13	634,375
Louisiana	493,976	493,958	4			460,321	406,826	5			627,885	570,153	11			789,393
Maine	348,233	345,696	3	2		209,733	209,733	2	1		139,758	139,758	1		5	279,164
Maryland	128,896	119,788	1		14	608,009	576,216	3	1		6,400	6,400			2	825,125
Massachusetts	491,527	490,263	4	2		31,039	31,039				320,890	310,839	1			2,025,042
Michigan	872,632	851,833	6	2	41	1,801,658	1,801,658	9	3	7	481,534	481,534		2	18	867,308
Minnesota	522,494	496,493	4	4	17	1,683,207	1,682,113	12	2		310,070	310,070	4	2	13	1,225,344
Mississippi	332,954	332,954	7			504,319	504,319	4	1		233,150	233,150	2			940,174
Missouri	450,998	449,119	3	1		1,367,377	1,367,377	8	3		1,319,348	863,928	3	2	1	1,521,518
Montana	842,767	842,206	9			290,905	206,333	4			178,767	178,767	3		4	425,734
Nebraska	734,287	732,099	19		40	946,195	946,195	8	2	9	38,117	38,117	1		4	748,388
Nevada	206,196	201,868		4	13	4,693	4,693				92,236	91,981	1		25	170,853
New Hampshire	102,433	101,921	7		1	181,248	181,212	4								392,776
New Jersey	463,987	463,987	1	2	1	542,654	542,654	3	1		225,737	225,737	2			1,529,653
New Mexico	123,381	122,378	3		1	230,046	230,046	2			20,902	20,902			6	645,923
New York	1,906,664	1,872,132	5	8		3,177,007	3,099,667	12	13		405,445	360,845		2	8	3,672,130
North Carolina	1,225,139	1,189,765	6	5	47	913,708	913,708	12	2	10	77,010	77,010		1	14	1,139,819
North Dakota	525,514	476,687	7	1		436,880	436,880	6		5	110,270	110,270	1		16	780,868
Ohio	545,780	530,780	8	1	4	2,155,153	2,084,201	12	2		701,970	686,780	2	1	13	3,010,809
Oklahoma	439,951	436,211	6		50	355,527	354,627	3	1		551,352	549,382	9		41	2,020,671
Oregon	173,428	171,720	2			307,391	218,374	3			37,918	32,000	1			558,332
Pennsylvania	1,676,971	1,465,072	2	3	2	1,344,225	1,344,225	12	1		948,724	701,000	6	1		4,843,667
Rhode Island	446,089	445,450	1	3		7,406	7,406				209,568	209,568		1		75,077
South Carolina	483,201	449,677	7	4	7	469,383	469,383	5	5		131,328	130,925		1	27	1,070,979
South Dakota	321,217	321,217	3	2	17	126,227	126,227	2	1		65,340	64,480	1		4	1,341,768
Tennessee	297,855	283,452		2	5	576,552	576,552	3	2		34,534	34,534	1			1,877,976
Texas	2,483,146	2,450,399	23	3	16	1,720,768	1,648,960	14		5	278,936	254,000	3		8	2,694,244
Utah	385,851	385,643	3		136	28,638	28,638			8	4,350	4,350			1	372,032
Vermont	32,093	27,207			7	206,402	206,402		2		12,043	12,043			3	252,060
Virginia	731,240	638,340	8	3	20	233,033	231,826	3	2		77,843	77,623	1		3	1,285,175
Washington	343,038	341,562	3	1	12	425,362	423,862	6	3		21,910	21,910			7	579,746
West Virginia	377,241	361,481	7		2	17,310	17,310	2			113,000	113,000	1		2	1,253,132
Wisconsin	889,268	878,511	9		11	1,004,757	958,634	8	3	2	274,499	267,661	1	1	9	1,388,345
Wyoming	139,774	120,314	1	1	8	89,337	89,337	1			327,458	294,000	3			350,475
District of Columbia	317,500	317,500	1			8,868	8,868				44,300	44,300	1			155,902
Hawaii	168,936	166,306	2	1	1	223,256	223,249	4			4,810	4,810			1	294,506
Puerto Rico	49,040	48,840	1			584,007	579,336	11								414,857
TOTALS	30,793,478	29,835,128	275	67	885	33,670,653	32,675,783	264	61	172	10,736,531	9,680,507	80	18	528	58,554,303